WIRELESS TELEGRAPHY

WIRELESS TELEGRAPHY

201 ILLUSTRATIONS

SECOND EDITION REVISED AND ENLARGED

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PREFACE TO SECOND EDITION

THIS, the second edition of *Wireless Telegraphy*, has been revised and considerably enlarged and now covers the most modern practice. In making the revision, the Author has had chiefly in mind the needs of seafaring operators and of students preparing for the Postmaster-General's certificate in Radio-Telegraphy. The earlier parts of the book have been amplified, forty-seven diagrams have been added, the section dealing with the Marconi Company's system has been considerably extended, and a glossary, which it is hoped will prove a useful feature, has been included. The Author gratefully acknowledges the hospitable reception of the first edition, the constant demand for which necessitated several reprints.

To the gentlemen who so kindly gave assistance in the preparation of the first edition, thanks are again tendered, as also to Mr. F. Furness for permission to photograph certain pieces of apparatus in his possession.

W. H. M.

WILMSLOW,
CHESHIRE.
1919.

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CHAPTER I

ELECTRIC OSCILLATIONS AND WAVES

Introductory—Condenser—Inductance—Electric Oscillations —Electric Waves—Resonance

In Hertzian-wave or Radio-Telegraphy we are concerned with operations carried on in an infinitely tenuous medium termed the aether, which fills all space and permeates all matter. In order that a wave-motion may be set up in any medium it is necessary that it should be endowed with elasticity—that is to say, with the ability to restore itself to its former condition after any force which causes a strain or distortion in it is withdrawn. Also it should possess inertia. As is well known, sound is due to a disturbance in the air, and if, say, a tuning-fork is caused to vibrate, the air in its neighbourhood will be carved into waves of alternate compression and rarefaction which will travel outward from the source at a rate depending on the ratio of the square root of the elasticity of the medium to its density ; in the case of air at atmospheric pressure the waves travel at a speed of about 1,090 ft. per second.

The distance between one place of maximum compression and the next is termed the wave-length of the sound, and is determined by the rate at which the source of the sound vibrates and on the velocity with which the disturbance is transmitted through the medium.

Suppose that we had two tuning-forks, one emitting a high note, the other a low note, if the forks are kept in vibration for the same length of time, say one second, the sound-waves from each source will have travelled the same distance, but the fork emitting the high note vibrates much quicker than the fork emitting the low note, therefore it must generate more waves and the length of each wave must be shorter. The length of the waves can be found by dividing the

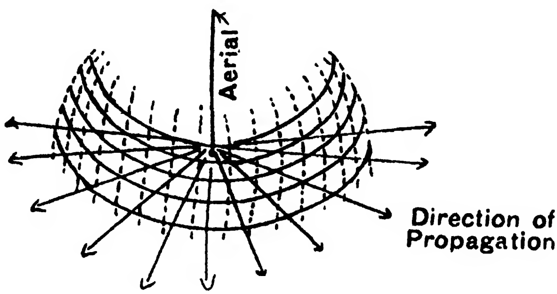

FIG. 1.

Dotted lines=electric component.
Continuous lines=magnetic component.

velocity of propagation by the frequency with which the source of the sound vibrates. Just as a vibrating mechanical body, such as a tuning-fork, sets up sound-waves in the air, so will electrical vibrations in a circuit set up waves in the aether. The vibration of particles producing sound-waves consists of a to-and-fro movement in the direction of propagation, but the aether is not competent to sustain a wave-motion of this kind. In the case of aether-waves the medium is displaced in a direction at right angles to the direction of propagation, and the electric and magnetic components of

which they are made up are also at right angles to each other and to the direction of propagation (Fig. 1). The aether-waves used in wireless telegraphy are produced by the charging and discharging of a condenser, and we shall now consider the means adopted for their production.

CONDENSERS

A condenser consists essentially of two conducting surfaces separated by an insulating material. The conducting surfaces are known as the plates of the condenser and the insulating material as the dielectric of the condenser. If such an arrangement be connected to a source of current, for example a battery of cells, an electro-static strain will be set up in the dielectric medium between the plates, and, if the plates are free to do so, they will attract each other and come together just as if they were connected by stretched india-rubber bands. Fig. 2 shows the closely adjacent plates of a condenser with the lines of force between them. These lines of force will continue to exist after the withdrawal of the charging battery, and the condenser is then said to be charged. If the plates of the condenser are connected by a conductor, a momentary current will flow through it and the lines of force will collapse, and the condenser is then discharged.

FIG. 2.
Showing direction of lines of strain in charged condenser.

The capacity of a condenser is equal to the quantity of electricity required to raise its potential to unity,

thus, if 1 unit of electricity raises its potential to 1, its capacity is 1.

A glance at Fig. 3 will perhaps make the matter plain. Suppose we have two glass vessels, the diameter of one, large compared with the diameter of the other, and of infinite height, and suppose the vessels have a graduated scale engraved on them, as, for instance, a

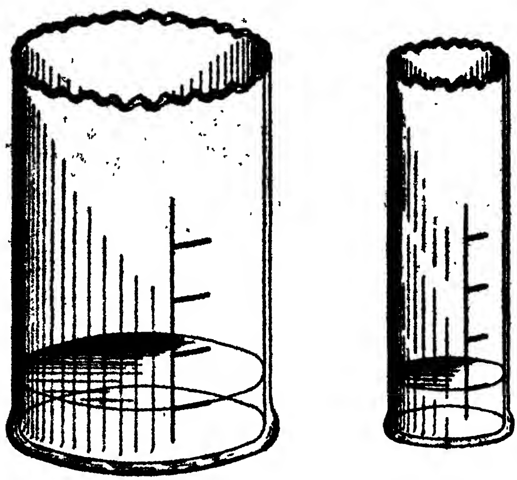

FIG. 3.

medicine-glass. As the height of the jars is infinite we cannot measure their capacity by the quantity of liquid which they will hold, because we can never fill them; but if we now pour liquid into both vessels and note the quantity required to raise the level one scale division in each case, we can say that in the first case the vessel has a capacity of 1, because unit quantity of liquid has raised the water level to 1, and in the second case we could, if it required 2 units of liquid to raise the level to 1, say that it had a capacity of 2.

The capacity of a condenser depends on the area of the opposing surfaces, on the distance between them, and on the nature of the dielectric. The capacity of a condenser with air as dielectric, providing the distance between the plates is very small compared with their area, can be found from the following formula—

$$C = \frac{S}{4\,\pi\,t}\,k$$

where S = surface of plates, π = 3·1416, t = thickness of dielectric, and k = dielectric constant.

From this it will be seen that the capacity varies directly as the area of the plates, and inversely as the thickness of the dielectric or distance between the plates.

Suppose now we had two condensers, the size of the plates and the distance between them being the same in both cases. If the space between the plates of one of them were filled by the insertion of a sheet of glass, we should find, if we measured the capacity in both cases, that the condenser with the glass dielectric had a much greater capacity than the condenser whose dielectric was air. This is due to the fact that the various insulating substances, such as glass, hard rubber, paraffin wax, etc., permit electro-static action to take place across them in varying degree. The ratio between the capacity of a condenser with a dielectric other than air and one which has an air dielectric, is known as the specific inductive capacity of the material, and to make use of the above formula to calculate the capacity of a condenser, we must first know the specific inductive capacity of the material used as dielectric. The dielectric constant of air is 1, and in the chapter

on measurements will be found a table giving the dielectric constants for materials most frequently used in the manufacture of condensers. It should be noted, however, that the dielectric constant varies enormously for different specimens of the same material, and therefore the use of the formula is practically restricted to air condensers.

ARRANGEMENTS OF CONDENSERS

Condensers may be arranged in two ways—in parallel or in series. Fig. 4 shows a number of condensers arranged in parallel. The total capacity when they are so connected is the sum of the separate capacities: for instance, supposing each of the condensers to have a capacity of 5 microfarads, the total capacity will be 15 mfds. Fig. 5 shows a number of condensers arranged in series. The total capacity in this case will be equal to the reciprocal of the sum of the reciprocals of the capacities, and will always be smaller than the smallest in the series. The capacity can be found from the formula

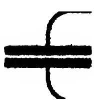

FIG. 4.
Condensers connected in parallel.

FIG. 5.
Condensers connected in series.

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} +}$$

where $C =$

total capacity, and C_1, C_2, C_3, etc., equal capacity of condensers in the series. As an example, suppose each of the condensers to have a capacity of 10 mfds., the sum of the reciprocals will be $\frac{1}{10}+\frac{1}{10}+\frac{1}{10}=\frac{3}{10}$ and the reciprocal of this is $\frac{10}{3}=3\cdot\frac{1}{3}$, therefore the total capacity of the three condensers in series is $3\frac{1}{3}$ mfds. It is quite a simple matter to see why the capacity should be smaller when condensers are connected in this way, as what we are in effect doing is to increase the thickness of the dielectric. In the above example the thickness of the dielectric has been increased three times and the capacity therefore reduced to one-third. If all the condensers in the series have the same capacity, the total capacity can be found by dividing the capacity of one by the number in series.

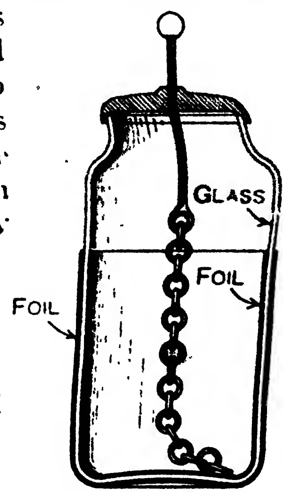

FIG. 6.
Leyden jar.

ENERGY STORED IN CONDENSER

A condenser may be considered as a device for storing energy in the form of an electro-static strain. The energy stored is equal to the energy expended in charging the condenser. In placing the first unit of electricity in the condenser, no energy is expended, as there is no force of repulsion to be overcome, each succeeding unit, however, requires the expenditure of

more energy, as the force of repulsion increases as the potential difference at the terminals of the condenser increases. The energy stored in a condenser is therefore equal to the product of quantity of electricity and the average voltage. If the quantity is reckoned in coulombs, the energy in Joules will equal $\frac{QV}{2}$. As $Q = CV$ the formula may be written $E = \frac{CV^2}{2}$, C being the capacity of the condenser in farads.

CONSTRUCTION OF CONDENSERS

The earliest form of condenser, the well-known Leyden jar—so named from the town in which it was discovered—consists of a glass jar, coated for a certain distance both inside and outside, with tinfoil. The foils form the plates of the condenser and the glass of the jar the dielectric; connection to the inner foil is made by means of a chain (Fig. 6). In the modern type, instead of tinfoil, the jar is coated electrolytically with copper. This is a great improvement, as the tinfoil frequently blisters and peels off. Fig. 7

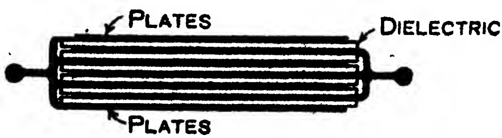

FIG. 7.

shows the method in which condensers are usually built; the size and number of plates, and the nature and thickness of the dielectric, will depend upon the

capacity required and the voltage to which it will be subjected.

Variable Condensers

Variable condensers may be classified under two heads, those whose capacity is variable in steps, and those whose capacity is continuously variable. An example of a condenser whose capacity is variable in steps is given in Chapter VI, Fig. 120; it will be seen that by means of three plugs, seven

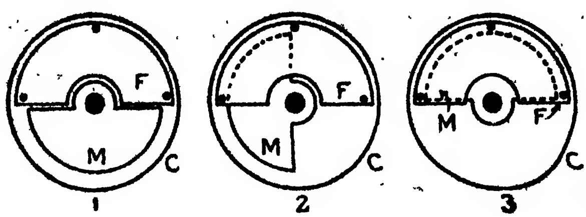

Fig. 8.
Showing construction of variable condenser.

capacity values can be obtained. A continuously variable condenser consists of two sets of plates, usually semicircular in shape, one set being fixed, the other capable of rotation through 180 degrees by means of a shaft on which it is mounted. If the plates are in position 1, Fig. 8, the capacity will be due entirely to the opposing edges of the plates, and will therefore be a minimum. As the movable set of plates is turned, the capacity increases, until, when position 3 is reached, it is at a maximum, as the whole area of the plates is then in use. The construction of these condensers can be seen from the illustrations in Chapter VIII, Fig. 145. Another form of

continuously variable condenser consists of two concentric metal tubes, the inner tube being insulated from the outer tube, either by air, or more usually by some solid dielectric material such as ebonite. The capacity is varied by sliding the inner tube, the capacity, of course, being a maximum when it is right inside the outer tube.

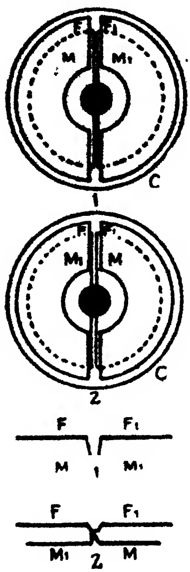

FIG. 9.
Marconi variable condenser.

MARCONI VARIABLE CONDENSER.

The Marconi Company extensively use a type of variable condenser, which, although depending on the same principle for the variation of its capacity, as the type first described, has the advantage that double the capacity can be obtained in a containing case of the same size. Fig. 9 shows the construction. It will be seen that there are two sets of fixed plates and two sets of movable plates, each of the sets of fixed plates being connected to one of the movable sets. The movable sets are carried on the same shaft, but are insulated from each other. The condenser will have minimum capacity when the plates are in position 1, each of the movable sets of plates being then under the set of fixed plates to which it is connected. If the movable plates are rotated through 180 degrees, they will be in position 2, and each of the movable sets will be under the fixed set of plates from which it is insulated. The capacity will then be a maximum. A

consideration of the drawing will show, that instead of two sets of semicircular plates facing each other, as was the case in the condenser first described, we now have two sets of practically circular plates facing, the capacity being thereby doubled. The dielectric in the case of the Marconi condenser, consists of discs of hard rubber, but the same principle could be employed in the construction of an air condenser.

INDUCTANCE

A current of electricity cannot be started in a circuit at once; it takes time to reach its full value. This is due to a property of the conductors forming the circuit termed *inductance*.

Consider for a moment a circuit consisting of a coil of wire, a battery, and a switch. When the switch is closed, a current of electricity will flow in the circuit and a magnetic field will be built up round the conductors. As the current is increasing in strength, the lines of magnetic force will cut across neighbouring portions of the circuit, and as a result an electromotive force will be set up which will tend to send a current round the circuit in the reverse direction to the current from the battery. The magnitude of this opposing electromotive force will depend on the inductance. It will thus be seen that if the inductance of a circuit is great, the time taken for the current to reach its full strength will be proportionally great.

In the same way, if the switch in the circuit is opened, the current will not cease immediately, because, as the lines of magnetic force collapse, they again cut across the circuit and set up an electromotive force which acts

in the same direction as the battery and tends to prolong the current in the circuit, the continuity of the circuit being preserved for a short time by the spark which takes place at the contacts of the switch as it is being opened.

Inductance may be defined as the inertia quality of a conductor, or the quality which resists changes being made in the strength of the current flowing in it.

The inductance, when magnetic material is absent, depends upon the length of the conductor. Coiling the conductor increases the inductance, and the insertion of an iron core will still further and very largely increase it. The inductance of a coil (from which magnetic material is absent) will, provided all the lines of magnetic force are linked with all the turns, vary as the square of the number of turns.

The unit of inductance is the henry, equal to 10^9 absolute units, and a conductor is said to possess unit inductance when the current through it, varying at the rate of 1 ampère per second, induces in it an electromotive force of 1 volt. For the purposes of wireless telegraphy, the henry is far too large a unit for the inductances employed; it is therefore customary to use a sub-unit, the millihenry, or the microhenry, which equal one-thousandth, and one-millionth of a henry respectively. Inductance is also frequently expressed in absolute units or centimetres: one microhenry equals 1,000 centimetres.

If the inductance is in a circuit conveying an alternating current, it may prevent the current from attaining any considerable value before the direction of the current is reversed, and will act just as a resistance would do in a direct current circuit, except that it

does not absorb energy. Coils of wire wound upon iron cores so as to have great inductance are, as a matter of fact, used to regulate the current in alternating-current circuits. If the reversals of the current are very high (as electrical oscillations), even a coil of comparatively small inductance will operate to choke them altogether, and will, in fact, behave to them as an insulator. This fact is made use of in wireless telegraphy installations to prevent high-frequency currents from flowing back and possibly damaging certain parts of the apparatus, as, for instance, the secondary winding of the transformer used to charge the condenser, although the inductance is not great enough to diminish appreciably the low-frequency current from the transformer.

Electric Oscillations

If a condenser be discharged through a conductor having a high resistance, the current will be in one direction only, and the discharge is said to be dead-beat, or non-oscillatory. If we plot the current in the circuit, against the time, the curve will assume the form shown in Fig. 10, it will be seen that it rises quickly to a maximum and

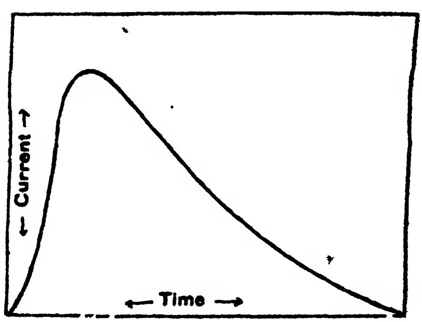

Fig. 10.

Curve showing dead-beat nature of condenser discharge through high resistance.

then dies down more slowly. If, however, the condenser be discharged through an inductive conductor of low resistance, say a coil consisting of a few turns of stout copper wire, the effect will be entirely different; the current in the circuit will be an alternating current—that is, a current which varies periodically in magnitude and direction. If there were no source of energy absorption in the circuit, the amplitude of each half-cycle would remain constant and the oscillations would be said to be undamped, but owing to the resistance of the conductor which forms the discharger, and the resistance of the spark-gap which is included in the circuit, the amplitude does not remain constant, but decays, as shown in Fig. 11, and the oscillations are said to be damped. The rate at which the oscillations in the circuit decay depends upon the resistance of the circuit, and in some cases the dielectric of the condenser is also a source of energy absorption and will therefore increase the damping.

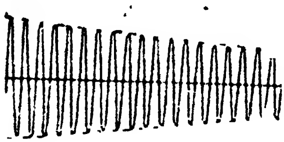

FIG. 11.

Showing oscillatory nature of discharge when resistance is small.

If the amplitude of the oscillations decays rapidly they are said to be strongly damped, and if the decay of the amplitude is not great, they are said to be feebly damped oscillations. The amplitude of each half-swing bears a constant ratio to the one preceding it, and if the Naperian logarithms of each amplitude are written down, it will be seen that they exhibit a constant difference: this difference is termed the logarithmic decrement of the oscillations. The number

of complete alternations of current per second in the circuit, is called the frequency of the oscillations. The frequency depends upon the capacity and inductance of the circuit and can, if the capacity and inductance are known, be found from the formula $n = \frac{5 \cdot 033 \times 10^6}{\sqrt{CL}}$ where n equals the frequency, C the capacity of the circuit and L the inductance. (C in mf., L in cms.)

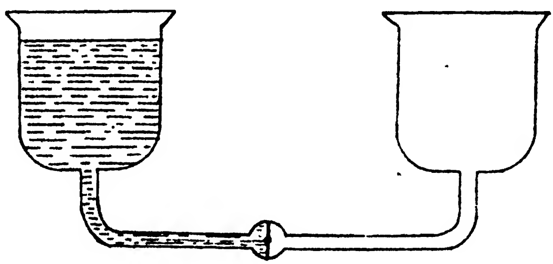

FIG. 12.

Fig. 12 shows in a modified form a hydraulic model of a Leyden jar or condenser, devised by Sir Oliver Lodge, and serves admirably to illustrate the fact that under certain conditions the discharge is oscillatory. The model consists of two glass jars, representing the two plates of a condenser; the jars are connected on their under side by means of a **U**-shaped tube provided with a stop-cock, the tube representing the discharger. Now suppose the stop-cock to be closed and one jar to be filled with water, also suppose that the **U**-shaped tube be partially filled with sand: if now the cock is opened, the water will rise in the second jar quickly at first, and, as the difference in level decreases, more

slowly, until the water is at the same level in both jars. This illustrates the case of a condenser discharged through a conductor of considerable resistance, the discharge in the electrical case being accompanied by a current in one direction only till the plates of the condenser are both at zero potential, and in the case of the hydraulic analogue by a flow of water in one direction only till the water-level is the same in both jars. Now suppose the sand-choked tube to be removed and replaced by another of fairly large internal diameter, and, the cock being closed as before, one jar to be again filled with water. On the stop-cock being opened the water in the first jar will rush through the tube into the second jar, but, owing to its inertia, it will not stop when the pressure in the two jars is equalised, but will continue to flow till the water in the second jar is at a higher level than that in the first; it will then flow through the tube in the reverse direction and again will not stop on the water obtaining equal level in the jars, but will continue to flow till the first jar is at a slightly higher level than the second. The operation will then be repeated till, by the viscosity of the water and the friction on the sides of the jars and tube, it is finally brought to rest and the water-level is the same in both jars. This serves to illustrate the oscillatory character of a condenser discharge through a conductor of low resistance. In the electrical case the discharge is accompanied by a current in the conductor which periodically reverses its direction and by the periodic reversal of the sign of the potential difference at the condenser terminals. In the case of the hydraulic model we have seen that on the stop-cock being opened—which represents

the passing of the spark in the electrical case—there was a current of water set up in the tube which periodically reversed its direction of flow, also, the difference in water-level in the two vessels periodically reversed, which is the analogue of the alternating potential differences of the condenser.

ELECTRIC WAVES

We have already seen that if a condenser is discharged through a conductor having inductance and small-resistance, oscillations are set up in the circuit. Suppose now that the condenser, instead of consisting of two sets of closely adjacent plates, consists of two plates widely separated, and connected to the inductance and spark-gap, as in Fig. 13; also suppose that

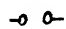

FIG. 13.

the inductance capacity and resistance are equal in both cases. If oscillations are set up in such a circuit we shall find that the decay in their amplitude is much more rapid (Fig. 14). This shows that some other source of energy dissipation has been introduced. The increased damping of the oscillations is due to the fact that a portion of the energy is radiated into space and does not return to the conductors of the circuit.

The first stage in the production of a wave (before the passing of a spark) is shown in Fig. 15. It will be seen that lines of electric strain stretch from one conductor to the other. Upon the passing of the spark the ends of the lines of strain move along the

conductor toward the spark-gap, the result being that some of them become completely closed and detached curves, by reason of the uniting together of their ends. The motion of the lines of strain along the conductors constitutes a current in them; therefore, during the formation of the closed loops of electric strain, a magnetic field is built up around them. The collapse of these lines of magnetic force will result in the condenser being again charged, but in opposite sense. At this stage the radiation of the wave commences and the

FIG. 14.

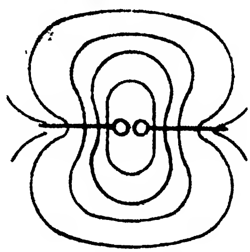

FIG. 15.

closed loops of electric strain, together with the magnetic field, which takes the form of expanding circles having the conductors of the circuit as their centre, are radiated into space. The speed with which the wave travels outward from the source depends upon the elasticity and density of the medium and is the same as the velocity of light—that is, 186,000 miles per second. This fact has led to the assumption that both light and electric waves are identical in nature, and that both are undulations in the same medium (the aether), differing only in wave-length. Like light, the electric waves can be refracted and reflected, as was demonstrated by Hertz.

RESONANCE

The means adopted by Hertz to detect the electric waves at a distance consisted of an open oscillatory circuit similar to Fig. 13, but the spark-gap was very finely adjustable by means of a micrometer screw. If such a circuit be set up at a distance from and parallel to the generating circuit, a stream of sparks will be observed to pass the micrometer spark-gap during the time the generating circuit is in action, the maximum

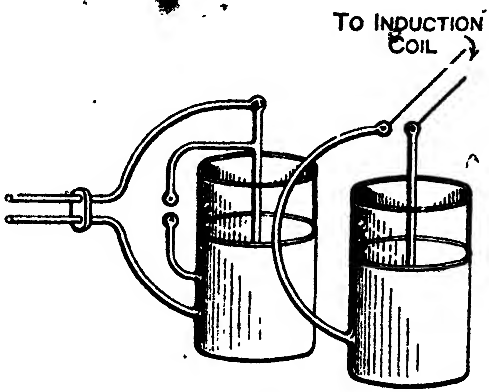

FIG. 16.
Lodge syntonic jars.

effect being produced in the detecting circuit when the product of its capacity and inductance equals that of the generating circuit. When the product of the capacity and inductance of one circuit is equal to that of another, the two circuits are said to be in tune, or in resonance, and will oscillate to the same frequency. The reason why the maximum effect is produced in the detecting circuit when it has the same frequency as the generating circuit is, that the effect of the waves is

cumulative and each impulse is received at the exact time when it will help to increase the amplitude of the oscillations already set up in the circuit. An example of how large a number of feeble impulses can, if they are administered at the right times, produce a great effect, is furnished by a heavy weight suspended by a cord or rope. If the weight is lightly pushed it will swing to one side, but the amplitude of the swing will be small; if a second impulse be administered at the moment it attains its maximum amplitude to one side or the other, the effect will be cumulative; and if a number of such impulses are administered, the weight will eventually attain a very great amplitude.

Sir Oliver Lodge has devised an apparatus for the demonstration of resonance effects, the construction of which is as follows: a condenser, usually a Leyden jar, and a conductor having inductance were joined across the spark balls of a Rhumkorff coil; another circuit, consisting of a capacity and variable inductance and having a small spark-gap shunted across the terminals of the condenser, was set up at a short distance from it. When the Rhumkorff coil was set going minute sparks were observed to jump across the small gap in the detecting circuit. The maximum effect being produced when, by the adjustment of its capacity or inductance, it had been brought into resonance with the generating circuit.

CHAPTER II

THE TRANSMITTER

Evolution of Transmitter from Hertz Oscillator—Direct and Inductive Coupling—Condensers for Transmitting Circuits—Inductances and Oscillation Transformers—Spark-gaps—The Aerial—Directive Aerial—Earth Connection—The Induction Coil—Accumulators—Morse Keys—Alternating Currents—Alternating Current Dynamos—Alternating Current Circuits—Alternating Current Transformers—Meters—Motor Starting Switch

WITH the means already described it would not be possible to carry on practical communication over any considerable distance, and it was not until Marconi brought out his first apparatus that a system suitable for the transmission of messages came into being. Marconi's first transmitter consisted of an induction coil, one side of the spark-gap being connected to an insulated vertical wire termed an aerial, the other side being connected to earth (Fig. 17). In the primary circuit of the induction coil was a Morse key, by means of which signalling was effected. It will be seen that this arrangement is a modification of the Hertzian oscillating circuit (Fig. 13): one arm being in a vertical instead of a horizontal position and the other arm

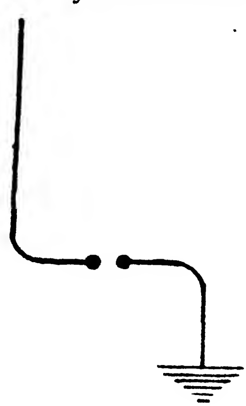

FIG. 17.
Marconi plain aerial.

replaced by the earth. The waves radiated from this type of transmitter will not be completely closed loops of electric strain, as was the case with the Hertzian oscillator, but semi-loops having their extremities on the earth, as shown in Fig. 18. The magnetic component will consist of expanding concentric circles having the aerial wire as their centre.

With such an arrangement, used in conjunction with the coherer receiver, it was found possible to carry

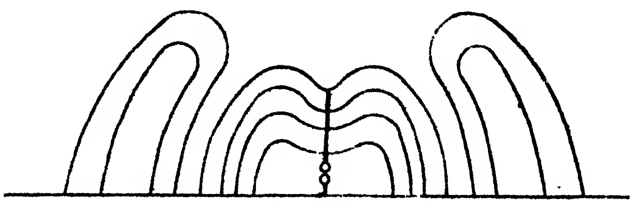

FIG. 18.

on communication over a distance of about 100 miles. With a transmitter of this kind it will be seen that the oscillations are generated in, and radiated from one and the same circuit. This circuit is an open, or good radiating circuit: therefore the decay in the amplitude of the oscillations will be rapid and the energy is practically concentrated in two or three swings. Now suppose a number of receiving stations to be within range: they will all respond to the signals sent out, because the amplitude of the first oscillation is great enough to actuate the detecting device. If we wish to confine the effect to one particular receiver, we must find means to spread the energy over a large number of comparatively feeble impulses, any one of which by itself would be insufficient to actuate the detector; in other words, we must find means to

generate and radiate feebly damped oscillations. Also we must adjust the receiver so that it has the same frequency as the transmitter. When this is done, the effect of the oscillations being cumulative, their amplitude will eventually be great enough to set the detector in action. A receiver having a different frequency will not be actuated, because the impulses, being administered at the wrong times, will be mutually destructive.

Another disadvantage of the plain aerial transmitter is that no considerable energy can be stored in it. The energy stored in a condenser is equal to half the product of its capacity and the square of the voltage to which it is charged, $E = \frac{CV^2}{2}$. The capacity of a vertical wire with respect to the earth is very small, therefore to impart large energy it must be charged to a very high voltage. The voltage to which the aerial is charged will be determined by the length of the spark-gap. The spark-gap cannot be indefinitely lengthened because as its length is increased its resistance increases also, which results in increasing the damping of the oscillations. The length of the spark-gap cannot advantageously much exceed one centimetre. The problem of selective wireless telegraphy resolves itself into this: That means must be found to generate and radiate feebly damped oscillations; also, if considerable distances are to be covered, the capacity of the generating circuit must be large in order that considerable energy may be imparted to it.

Sir Oliver Lodge's solution of the problem is a compromise between an open or good radiative circuit and a closed circuit which is a persistent oscillator and has

large energy storage, owing to the large capacity which may be given to it.

Fig. 19 shows the form which his aerial takes. A and B are capacity areas connected one to each side of the spark-gap; included in the leads are variable inductances for tuning. Such an arrangement, by

FIG. 19.

Lodge aerial.

increasing the capacity, enables a much larger amount of energy to be stored, also, as it is a partially closed circuit, the oscillations in it will be more persistent, although the radiating properties it possesses are less than those of the vertical wire before mentioned.

The practical disadvantages of the arrangement are

that four masts are required, also considerable ground-space, for its erection. For ship working it would, of course, be impossible, or at the best, very inconvenient to put up such an arrangement. Other investigators tackled the problem in a different way, by using a closed or non-radiating circuit in which to generate feebly damped oscillations, and then transferring them to an open circuit from which they are radiated. The capacity of the condenser in the closed circuit can be made large, and therefore the energy storage will be great.

There are several methods of coupling the open and closed circuits together. Fig. 20 shows what is known as the direct method of coupling, the closed circuit consists of a condenser joined in series with a spark-gap and an inductance. The aerial and earth are connected to two points on the inductance, as shown in the diagram. If a large number of the turns of the inductance are common to both circuits the coupling is said to be close, and if a few turns are common to both circuits the coupling is said to be loose. The second or inductively coupled method is shown in Fig. 21. In this case the closed circuit is constituted as before, but the aerial and earth wires are connected to a second coil. If this second coil be placed in such a position, with respect to the first, that all the lines of

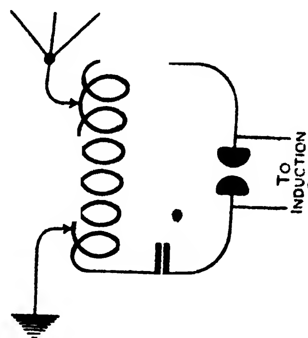

FIG. 20.—Oscillatory circuits of directly coupled transmitter.

magnetic force which come into being when oscillations are set up in the closed circuit cut across all the turns in the second coil, the coupling is said to be close, and if it is placed in such a position that only a few of them cut across it, the coupling is said to be loose. When the coupling between the circuits is *close*, the energy passes from the closed to the open circuit rapidly, and *close coupling therefore increases the damping of the oscillations.* If the coupling between the circuits is *loose*, the energy passes slowly from the generating to the radiating circuit, and the damping of the oscillations will be small. There is no essential difference between direct and inductive coupling and in both cases it is necessary that the open and closed circuits should be adjusted to the same frequency. If this is not done, the oscillations in the primary or generating circuit will not be effectively transferred to the open circuit. A convenient method of ascertaining when the two circuits are in tune is to insert a hot wire ampère meter in the earth wire and adjust the circuits till it gives the largest reading.

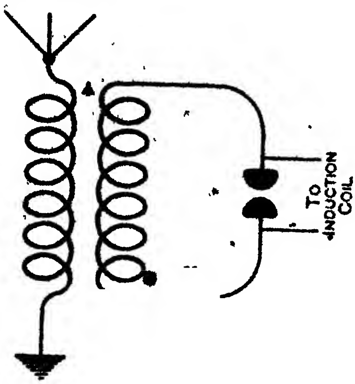

Fig. 21.—Oscillatory circuits of inductively coupled transmitter.

When two circuits are coupled together there will be mutual reaction between them, which results in oscillations of two different frequencies and therefore different wave-lengths being emitted. One of the

wave-lengths will be greater and one less than the natural wave-length of the circuit. If the coupling between the circuits is close, the difference between the wave-lengths will be great, but as the coupling is made looser they approach, till, when a certain degree of coupling is reached, they are so nearly equal as to practically merge into one. The radiation of waves of two lengths by the transmitter is a disadvantage, because as well as actuating receivers tuned to either wave-length, and thereby producing interference, part of the energy radiated is wasted, as the receiver can only make use of the energy of the wave-length to which it is tuned. The coupling of the transmitter circuits therefore should be loose, in order to concentrate the whole of the energy radiated into one wave-length and to keep interference at a minimum. The coupling, however, cannot be loosened beyond a certain point without reducing the intensity of the radiated waves and therefore reducing the working distance.

The measurement of the coupling co-efficient is dealt with in the chapter on measurements.

Condensers for Transmitting Circuits

In the construction of a condenser for use in the transmitting circuit we have to consider what material used as a dielectric will absorb least energy; also we must so construct it as to withstand the high voltage to which it will be subjected.

The losses in a condenser may be classed under three heads: first, the dielectric losses due to hysteresis; secondly, those due to brushing from the edges and corners of the plates; and, also, as a current is flowing

in and out of the condenser during the time it is charging and discharging there will be some energy absorption due to the resistance of the plates, but if these are made of good conducting material, and are fairly stout, the loss will be so small as to be negligible.

The hysteresis losses vary considerably with the material of the dielectric, and also with the frequency, being greater for high frequencies. The measurement of condenser losses is dealt with in a later chapter.

In respect of internal losses, an air condenser would be ideal, as the internal losses when air is the dielectric are nil. We are, as a general rule, however, faced with a practical difficulty—namely, the space required for the housing of such a condenser, as, owing to the fact that the dielectric strength of air is small, the plates would have to be a considerable distance apart to withstand the pressure. In practice, therefore, the types of condenser most frequently met with are those consisting of metal plates arranged in a containing vessel and immersed in oil—the oil forming the dielectric—and those in which the dielectric is glass. These also are frequently immersed in oil: the object being to prevent brushing from the edges of the plates. On small-power installations the well-known Leyden jar is by far the most generally used.

The specific inductive capacity of glass is very high, being about nine times as great as air. This, together with the fact that it has great dielectric strength, enables the condenser to be kept within reasonable dimensions. The jars are built up in groups, sufficient being put in series to safely withstand the tension, and then in parallel till the required capacity is obtained.

If the jars show considerable brushing while in use, an improvement may be effected by putting more jars in series and so lessening the tension across each jar; but if this is done it will, of course, be necessary to add more in parallel to bring the condenser back to its original capacity. The measurement of the capacity of condenser will be dealt with in the chapter on measurements.

INDUCTANCES

In the chapter on high-frequency resistance, we shall see that the resistance of a solid metallic conductor of large section is not the same for currents of high and low frequency, but may be much greater for the former by an amount which depends partly on the frequency and partly on the thickness of the wire, the reason being that high-frequency currents, or oscillations, confine themselves to the surface of the conductor and penetrate to no appreciable depth. We shall also see how this increase in resistance may be avoided by using conductors built up of a large number of small wires insulated from each other and joined in parallel.

If an auto-transformer is used it is not practical to construct it in this way, the reason being that connection must be made by clips and to any part of the coil. It is therefore made of flat copper strips, or from copper tubing, which, having a large surface, tends to keep the high-frequency resistance low. The practical shapes taken by the inductances can be seen by reference to the photographs of the various systems.

If magnetic or inductive coupling is used, the coils of the transformer are made from conductors built up of a large number of insulated wires laid together.

The methods adopted for adjusting the coupling between the coils vary. In some cases the coils are cylindrical, one coil having a smaller diameter than the other and being stood within it; the coupling in this case is varied by withdrawing the inner coil more or less. In other cases the coils are made to slide over each other; this type is greatly used by the Marconi Company, and examples of its construction can be seen by referring to the description of their 1½ and ½ kilowatt sets.

SPARK-GAPS

The spark-gap takes various forms: in some systems the spark is taken between blunt rods, in others between balls. Plates and rings are also used; but never sharp points, as these cause premature discharge. The chief point to be considered in a spark-gap is its resistance, which should be kept as low as possible.

It has been found that the resistance of a spark-gap decreases with its length till a certain point is reached, after which it increases with the length of the spark-gap, rapidly if the condenser discharging across it is small, and less rapidly as the condenser is made larger. The length of the spark to give best results for any given transmitter is best found experimentally. A hot wire ammeter should be included in the aerial and, assuming that the circuits have already been tuned to each other, the spark-length should be varied until the greatest reading is shown on the ammeter. The resistance of the spark-gap, however, varies not only with its length, but with the quantity of electricity discharged across it. Thus, for a given length of spark the greater the quantity of electricity the less

will its resistance be. For this reason the condensers in the circuit are given as large a capacity as possible.

The voltage required to break down the insulation of the spark-gap depends on the length of the gap, and the size and shape of the discharger. If the latter consists of balls, the greater the radius of the balls the larger will be the voltage required to break down the insulation of the air-gap; and as it is very important that there should be no brushing or premature discharge, the balls should be of fair size and kept quite smooth.

The disruptive voltage when the spark is taken between points is approximately 30,000 volts per centimetre for spark-lengths up to 2 or 3 centimetres, after this it is somewhat less, as the dielectric strength of air is relatively greater for small thicknesses.

The spark-gap is sometimes placed in a compressed-air chamber, as the voltage required to break down a given spark-length is much greater in compressed air than in air at ordinary pressure: consequently the condenser can be charged to a much higher voltage. The noise from the spark is very great, and it is therefore the practice to enclose it in a muffled chamber, or else to place it in a room by itself, away from the operator. The ozone which is given out by the spark is also very objectionable, and means are therefore taken to conduct it to the outer atmosphere.

The Rotory Spark-gap

The Marconi Company have brought forward of recent years a spark-gap which consists of two discs rapidly rotated, the spark taking place between their peripheries. This form of spark-gap can be used either with direct or alternating current. The

advantages claimed are: that, although a true oscillatory discharge may take place across the gap, the rapid relative motion of the discs effectually prevents the formation of an arc. When used with direct current, the oscillations generated are practically continuous and undamped. This discharger, when used with an alternating-current supply, consists of a metallic disc carried on the shaft of the alternator but insulated from it, the disc is fitted with transverse or radial studs equal in number to the poles on the alternator. Two fixed, insulated electrodes, mounted on a carrier of some insulating material, and capable of being rotated through a certain number of degrees about the axis of the disc, are connected in the primary oscillatory circuit (Fig. 22). The spark takes place at the moment the moving studs approach the fixed studs, and during the greater part of the time the condenser is discharging, the spark-gap is practically short-circuited, and the resistance of the circuit and consequent damping of the oscillations reduced. By adjusting the position of the fixed studs, the condenser discharge can be made to take place at the moment maximum voltage is reached and as the number of studs is equal to the number of poles on the machine, one discharge takes place for each half-cycle of current. Another type of rotary discharger now much in use has a larger number of studs on the rotating disc than there are poles on the machine, thus giving a number

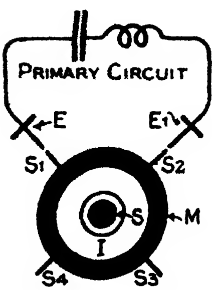

FIG. 22.

E, E_1. Fixed electrodes.
S. Shaft of alternator.
S_1, S_2, S_3, S_4. Radial studs.
I. Insulating material.
M. Metal ring.

of discharges for each half-cycle. On the Marconi 1½ kilowatt Transmitter, the machine has 4 poles and the number of studs on the disc is 24. The advantages claimed for the rotary gap are: greater efficiency, as, owing to the rapid opening of the gap, there will be no reflux of energy to the closed circuit, consequently a much closer coupling may be used; reduction of damping due to spark resistance as the gap is rapidly shortening in length during the time the condenser is discharging; greater regularity of sparking, as, should the transformer voltage fall below its usual value, the spark will not miss but will take place a little later; one wave-length only produced, as the energy being transferred to the open circuit and the coupling broken by the opening of the spark gap, the aerial circuit oscillates to its own natural frequency. In the case of the 24-stud disc, a higher spark frequency is obtained, which is much easier to read through atmospherics, and also as the condenser is not charged to the maximum transformer voltage, but to some smaller voltage, the insulation of both the closed and open oscillatory circuits is much more effectual. The aerial used with a rotary discharger should be of the slow radiating type, as the energy is rapidly transferred to the open circuit, and the damping of the oscillations is therefore largely determined by the rate of radiation. Examples of rotary gaps are given in the descriptions of the Marconi ½ and 1½ kilowatt sets.

THE AERIAL

The aerial is that portion of a radio-telegraph installation which radiates or absorbs energy. It

consists, in its simplest form, of a single vertical wire, but the modern practice is to have a number of wires in parallel. This has the effect of increasing the capacity, and therefore the amount of energy that can be put into it. It also diminishes the resistance of the aerial and thereby reduces the damping. The wires should not be too close together, but well spaced, if the full benefit in increase of capacity is to be obtained; this is owing to the fact that if they are close together the distribution of the lines of force is unsymmetrical for each wire. The capacity of an aerial varies approximately as the square root of the number of wires in parallel, thus, four wires would have about twice the capacity of a single wire providing they are fairly well spaced. The best material for an aerial is copper or bronze wire, preferably stranded, 7/20 is a very convenient size. The form the aerial will take depends upon circumstances—such as amount of ground available, number of masts, etc. Fig. 23 shows a very convenient type; it consists of four wires connected together at the masthead and spread out by means of a rope like an inverted fan. The wires are then bunched together at their lower ends and led into the station. If two masts are available, an excellent aerial can be constructed, as in Fig.

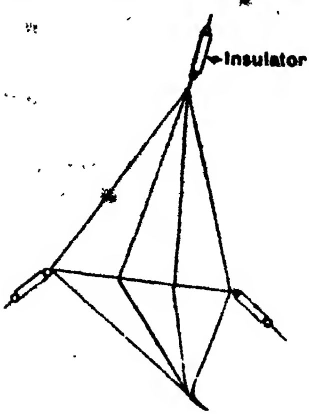

FIG. 23.
Inverted fan aerial.

24. A favourite type of aerial for a land station is that shown in Fig. 25, and is known as an umbrella

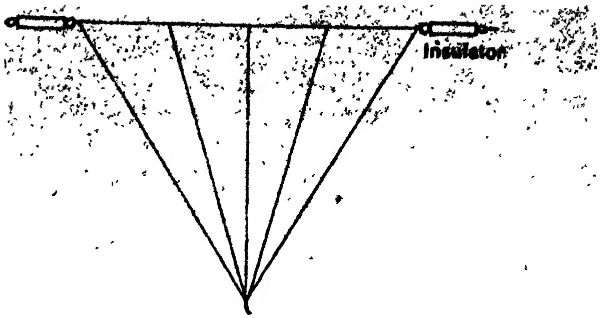

FIG. 24.

aerial. It consists of a vertical portion from the top of which radiate a number of wires like the spokes of a wheel; these wires should be connected at their

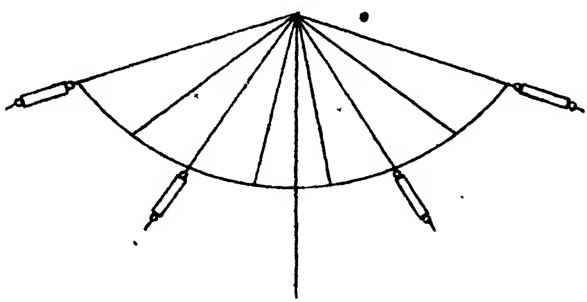

FIG. 25.
Umbrella aerial.

lower ends to another wire which encircles the mast; the horizontal wires, while they do not increase the radiation, add largely to the capacity of the aerial. As regards aerials for ships, there is not much choice as to shape, and they usually consist of a number of

wires stretched horizontally between the masts, the perpendicular portion being connected to the middle, as shown in Fig. 26, or else to one end as shown in Fig. 27. The former is known as a T-shaped aerial,

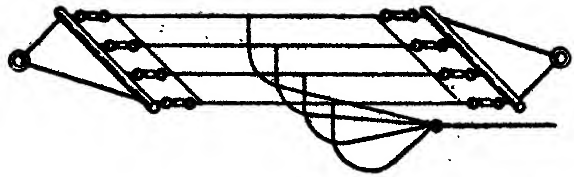

FIG. 26.
Ship's aerial.

the latter as an L-shaped aerial. The point at which the vertical wires join the horizontal, is largely determined by the position of the operating cabin, the T-shaped aerial being used if the cabin is amidships,

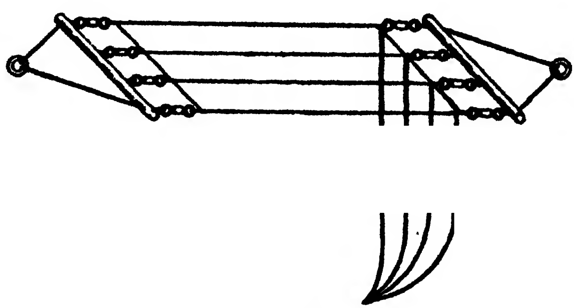

FIG. 27.
L-shaped aerial.

the L-shaped aerial if the cabin is fore or aft. An important point in building an aerial is its natural wave-length, which should not be very different from the normal working wave-length of the station. An

aerial will radiate best on its natural wave-length, if the wave-length is much increased by the addition of inductance in series, or much reduced by the insertion of a series condenser, the radiative properties will be considerably lessened. The natural wave-length of an aerial can be approximately calculated from its dimensions, a simple vertical wire will have a natural wave-length equal to about 4·5 times its length, a T-shaped aerial will have a natural wave-length equal to 4·5 times the vertical plus half the horizontal length, and an L-shaped aerial will have a natural wave-length equal to about 4·5 times the horizontal plus the vertical length. The radiation from a T-shaped aerial will be more symmetrical than that from an L-shaped aerial, but the latter will give a greater natural wave-length.

Care should be taken in the construction of an aerial to keep it free from points and sharp edges, as brushing is likely to take place from these and the efficiency of the transmitter is thereby impaired. To sum up, the qualities it is desirable that the aerial should possess are: good radiation, low resistance to high frequency currents and good insulation, which, in the case of conductors carrying high-frequency currents, means that not only should they be well insulated for conduction currents, but that they should be kept away from all earthed metal work, as, if they are near to it, and especially if they are parallel to it for any distance, a dielectric current passes.

Directive Aerial

The energy from an ordinary vertical aerial is radiated equally in all directions. This, in the case

of ship stations, is an advantage, because it is not till communication has been established that the position of the ship can be known. In the case of communication between two fixed points it would be advantageous if the energy could be concentrated in the direction of the receiving station, as not only would less interference result, but also the effect produced on the receiver would be greater by reason of the concentration.

The Marconi Company for their Transatlantic stations use a type of aerial which, while it does not concentrate wholly in one direction, confines the action

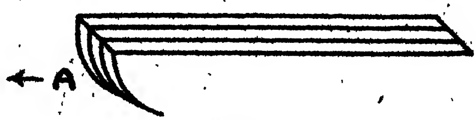

FIG. 28.
Marconi directive aerial.

of the transmitter mainly in the direction of the receiving station. This type of aerial is shown in Fig. 28: it consists of a vertical portion and a horizontal portion, the length of the latter being great compared with the vertical portion.

With an aerial of this kind the lines of electric strain will stretch much farther out into space in the direction A than in any other direction, because the horizontal portion concentrates them between itself and earth. The field of action of such a transmitter is roughly like the figure 8, the maximum effect being produced in the direction A, a second but smaller maximum being produced in the opposite direction, whilst in directions approximately at right angles very little effect is produced.

The point at which the detachment of the wave occurs is not at the aerial itself, but at a distance equal approximately to one quarter of a wave-length from it. Between this point and the aerial the movement of the lines of strain is sometimes inward, as part of the lines reconnect with the aerial, but from the point outward from the aerial, the movement of the strain lines is uniformly outward or away from the latter. The intensity of the field produced about the aerial diminishes approximately as the cube of the distance from it. The result of the concentration of the lines of force by the horizontal part of the aerial is that in certain directions the field produced at the point where the wave is radiated is very weak, whilst in the direction A, where the lines stretch far out into space, the strength of the field is great.

Insulation of Aerial

It is very important that the insulation of the aerial should be of the most perfect description possible. The potential is greatest at the upper part, and it is therefore of the first importance that the masthead insulators should be efficient. A form of insulator commonly used consists of an ebonite rod one or two feet in length and about one and a half inches in diameter, the rod having a screw-eye at each end. They are connected to the aerial wires and to the spreader, as shown in Figs. 26 and 27.

The second point at which special attention must be paid to the insulation is the point at which the aerial is led into the operating-room.

Fig. 29 shows a type of insulator much used. It

consists of a porcelain tube corrugated on the outside to increase the effective surface and having a metallic rod passing through it which has a terminal at each end: the aerial is connected to the outer terminal and the lead to the instruments to the inner terminal.

A type of leading-in insulator, almost exclusively used by the Marconi Company and called by them a Bradfield insulator, consists of an ebonite tube three or four feet in length and having, as in the former

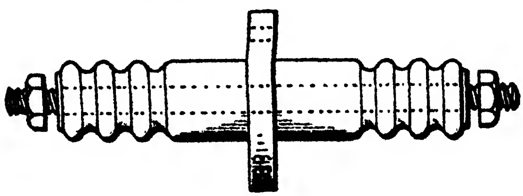

Fig. 29.
Leading-in insulator.

case, a metallic core passing through it. At the outer end, in addition to the terminal by means of which electrical connection between the aerial wires and the instruments is effected, is a shackle, the purpose of which is to remove all mechanical strain from it. Instead of being corrugated, a number of ebonite discs are threaded over the tube and serve the same purpose. A metal hood is provided to keep the upper part of the insulator dry.

Earth Connection

Great difference of opinion exists as to the advisability of earthing the aerial, Sir Oliver Lodge maintaining that the earthing of an aerial is inimical

to very sharp tuning. The general opinion, however, is that the aerial should be earthed, and that if the system of earth wires is properly constructed it is beneficial and increases the distance over which signalling can be carried on. In the early days of Radio-Telegraphy it was a common practice to use a copper plate buried in the ground as an earth, but by experiment it was found that the best earth connection was formed of a large number of wires laid in the ground radially from the station and stretching out from it as far as possible. It is not necessary that the wire should be deeply buried: if the station stands on grass-land, it is sufficient to turn up the turf, insert the wires and replace it. At the point where the wires meet they are connected together and led into the station. Fessenden, in America, devised what he called a wave chute, which consists of an arrangement of wires identical with that above described, the wires, however, being laid on the surface of the ground and not buried. In a ship station the earthing is effected by connecting to the side of the vessel.

The lead from the instruments to the point at which it is connected to earth should in all cases be as short as possible.

The Induction Coil

In small power installations the condenser is charged from the secondary terminals of an induction coil. For the benefit of readers not already acquainted with this piece of apparatus we append the following description—

The coil consists of a soft iron core C (Fig. 30), which is built up of a large number of soft iron wires

insulated from each other by varnish. The object of thus subdividing the core is to prevent eddy currents from being set up in it and the consequent loss of energy. Over the core is a winding of thick insulated copper wire P (Fig. 30); this is known as the primary winding. Over the primary winding is wound a large number of turns of fine insulated copper wire S (Fig. 30), which is the secondary winding. The ends of

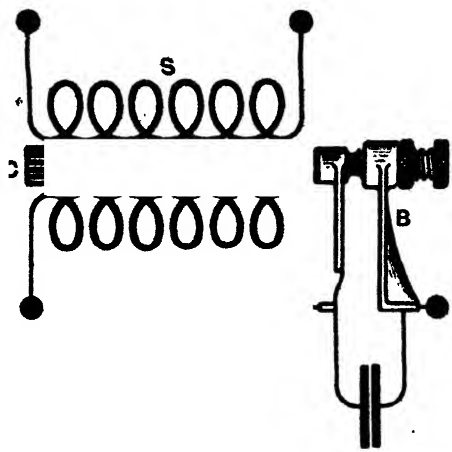

Fig. 30.

Induction coil.

this winding are brought out to terminals, which are also connected to the spark-gap.

The secondary is not usually wound on in layers extending the whole length of the coil, but in small sections, the object being to prevent high differences of potential from existing between neighbouring turns, which might break down the insulation. One end of the primary is connected to a terminal, the other end

being connected to one side of the contact-breaker B (Fig. 30), the other side of which is connected to a second terminal. The contact-breaker consists of a small disc of soft iron carried at the end of a metal strip. The iron disc is termed the armature and as mounted, is exactly opposite, and close to one end of the core. Behind the spring carrying the armature is a brass pillar which has a platinum-tipped adjusting screw, by means of which the play of the armature and the tension on the spring can be adjusted; across the contact-breaker a condenser of large capacity (about 1 mf. for a 10-in. coil) is connected. The action of the coil is as follows: When a battery is connected to the primary terminals a current will flow through the primary winding and the core will be magnetised; as the magnetism of the core is increasing the lines of force will cut across the secondary winding and, as is well known, an induced current in the secondary will result. The core being magnetised will attract the armature which, by pulling the platinum contacts apart, will break the circuit, and the lines of magnetic force brought into being by the current in the primary will collapse and again cut the secondary winding, and an induced current will be again set up in the secondary, but in the reverse direction to the first. It will be seen that as soon as the core loses its magnetism the armature will be released and the platinum contacts will again come together, and the cycle of operations will be repeated as long as current is supplied to the coil.

At the moment the armature is attracted by the core a bright spark, due to the self-induction of the primary winding, will be seen at the contacts of the

contact-breaker. This spark tends to prolong the current in the primary, and therefore the collapse of the lines of force will not be very sudden. The voltage

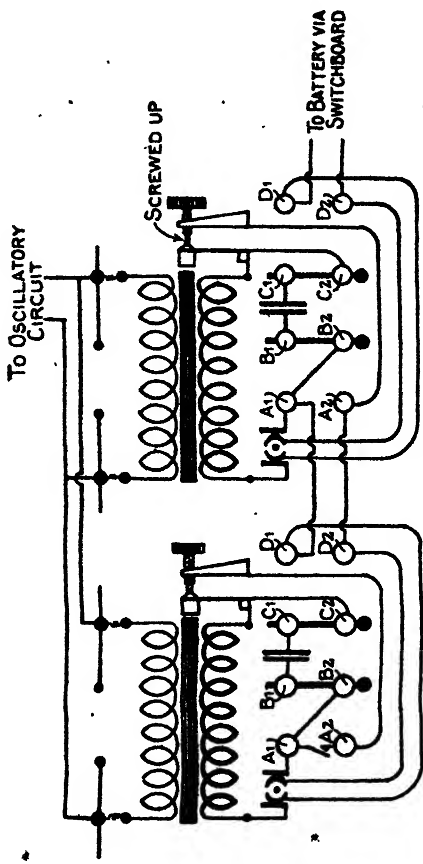

Fig. 31.
Showing two Marconi coils connected together.

produced at the secondary terminals will depend upon the number of turns of wire on the secondary winding, upon the number of lines of force cutting it, and upon

the speed at which they cut it. If now means can be found to prevent the sparking at the contacts of the coil a much greater effect will be produced in the secondary. The condenser connected across the contact-breaker does this, as the current due to the self-induction of the primary flows into and charges it every time the circuit is broken, instead of forming the spark at the contact-breaker. It will thus be seen that the induced current in the secondary at break is much greater than at make, and the discharge will therefore be uni-directional, as the effect produced at make, is too small to cause a spark at the discharger. On some Marconi installations, two coils are connected to work together, the primaries being connected in series, and the secondaries either in series or in parallel as required. The current through the primary windings is controlled by one contact-breaker only, the other being screwed up. Fig. 31 shows the simplest way to connect two Marconi induction coils together.

Accumulators

Accumulators, or secondary cells, are of two types; the pasted type, and the formed type. In the case of the pasted type the plates are prepared by pressing oxide of lead into a leaden grid so formed that the paste shall make intimate contact with it, and be firmly held in position. The plates are immersed in dilute sulphuric acid and held apart by glass rods or by corrugated celluloid separators. If now they are connected to the poles of a direct-current dynamo, or other source of direct current, electrolytic action takes place, which still further oxidises one of the plates, whilst on the other plate the oxide is reduced

and the lead rendered spongy or porous: the spongy plate is termed the negative plate the other being the *positive*. *The plates may be distinguished by their* colour, the positive plates being a dark chocolate *colour and the negative plates grey. The terminals* of a secondary cell are marked + and −, that marked + being the positive terminal and that marked − being the negative terminal. In the formed type of cell the active material is produced by electro-chemical means. The capacity of an accumulator is determined by the active area of positive plate, for this reason there is usually one more negative than positive plate in each cell, in order that both sides of each of the positive plates may be active. The capacity of a cell is reckoned in ampère-hours. An accumulator cell when fully charged, has a voltage of about 2·3 volts, and the acid a gravity of 1·215, the voltage should never be allowed to fall below 1·85 and the gravity of the acid should not be lower than 1·18. To charge such a cell or group of cells the following procedure should be adopted: The positive plate of the accumulator should be connected to the positive pole of the charging dynamo, and the negative plate to the negative pole of the dynamo; included in the circuit should be a variable resistance to regulate the charging current. A convenient form of resistance to use when charging accumulators is the ordinary carbon-filament incandescent lamp. A board should be obtained, and on it should be mounted a number of lamp-sockets connected in parallel; now obtain a double-pole double-throw switch and connect the accumulators, the switch, and the charging dynamo, as shown in Fig. 32. A lamp should now be inserted in one of the

sockets, and the switch put first in one position, and then in the other, and the brightness of the lamp noted. The correct charging position will be that in which the lamp is the least bright, because the voltage *of the accumulator is then in opposition to the voltage of the dynamo, or, in other words, the positive pole of the dynamo is connected to the positive pole of the*

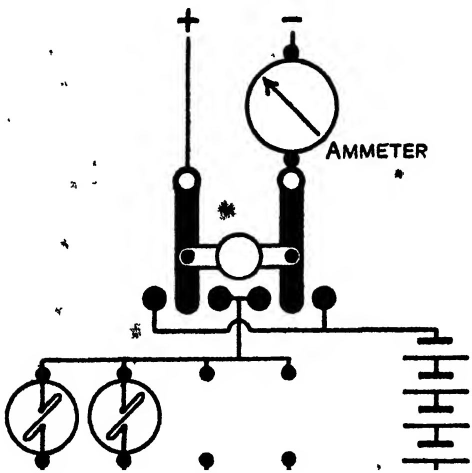

Fig. 32.
Accumulator charging.

accumulator. The correct charging current is obtained by inserting more lamps in the sockets until the ampère meter shows the right reading. The lamps must, of course, be of the same voltage as the charging dynamo. Violent gassing of the acid, indicates that the cells are fully charged. The faults most likely to occur are the following: Buckling of the plates, due in most cases to excessive rate of discharging; the same cause

is also frequently responsible for the disintegration of the plates which sometimes occurs. Another fault to be guarded against is the sulphating of the plates, an insoluble substance termed sulphate of lead forming on the plates, the cause may be any of the following: too strong a solution of acid, discharging the cell too low, by under-charging or leaving the cell partially discharged for long periods without removing the acid. *The remedy* is to give the cells a prolonged charging at a low-charging rate. The acid solution is made up of about three parts water to one part commercial sulphuric acid, the specific gravity of the acid solution being about 1·2.

Most makers of storage batteries send out full instructions with them as to charging and discharging rates, and general treatment—and it will conduce to the long life and satisfactory working of the cells if these instructions are faithfully followed.

Morse Keys

For small-power installations the Morse keys used are not very different from those employed in ordinary land-line telegraphy, the only difference being that the platinum contacts are larger; when, however, it is desired to interrupt large currents, precautions must be taken to eliminate the heavy sparking which occurs when the key is opened. Fig. 33 shows a form of Morse key much used in the larger installations; it will be seen that the contacts of the key are immersed in oil, which, when the circuit is broken by the opening of the key, flows into the gap and effectually prevents the formation of an arc. In some installations sparking at the key is eliminated by shunting a condenser

of large capacity across the contacts. For use on an alternating-current circuit a key shown diagrammatically in Fig. 34 is sometimes used. It is known as a

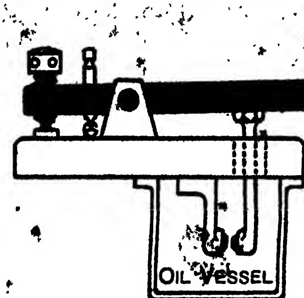

FIG. 33.
Oil-break key.

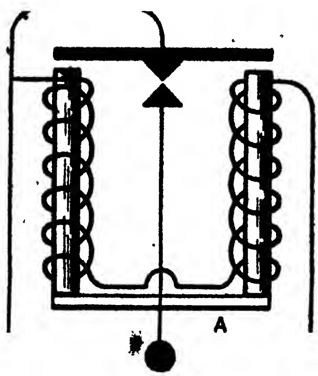

FIG. 34.
Magnetic key.

minimum break key, and its action is as follows: when the circuit is closed by the depression of the Morse key, the current flows through the coils of the

magnet A, which forms part of the circuit. The magnet, being thus excited, attracts the armature and closes a second pair of contacts which are in shunt with the contacts of the Morse key. If now the Morse key is opened the auxiliary contacts will not immediately follow but will remain closed until the alternating current is at or near zero. It will thus be seen that there is no danger of an arc forming, as the circuit is not broken until the current is practically nil. The

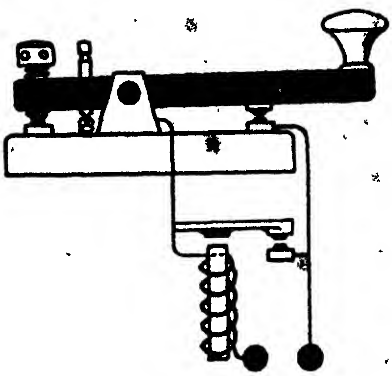

FIG. 35.

key is provided with two adjusting screws: one to regulate the play and the other to regulate the tension of the spring which pulls the contacts apart when the excitation of the magnet is too feeble to hold the armature. Fig. 35 shows the way in which the minimum break key is connected in circuit and with the signalling key.

Fig. 36 shows the construction of the magnetic key as used by the Marconi Company. To adjust the key, depress the armature till it touches the pole-pieces of

the magnet, then adjust the lower contact to such a height that it just raises the armature clear of the pole-pieces. Tension should now be put on the spring, and the upper contact adjusted so that there is a space of about $\frac{1}{32}$ part of an inch between it and the

FIG. 36.

Marconi magnetic key.

lower contact when the key is at rest. The final adjustment should be made, with the power applied to the circuit, the tension and play being adjusted till the sparking at the Morse key is reduced to a minimum.

ALTERNATING CURRENTS

If a current of electricity periodically passes through a series of changes, both in direction and strength, it is termed an alternating current. The time taken by one complete cycle of changes is termed the period, and the number of cycles per second is the frequency of the alternating current. Fig. 37 illustrates the cycle

of changes. The divisions along the line X Y represent intervals of time, and the strength of the current at any instant is represented by the length of the ordinal above or below the line X Y, according to whether it is positive or negative. Starting at the point X the current value is zero, as we continue along the line X Y it increases in value till at the point M it is at a maximum. It then diminishes till at the point Z it is again zero; then changing its direction of flow

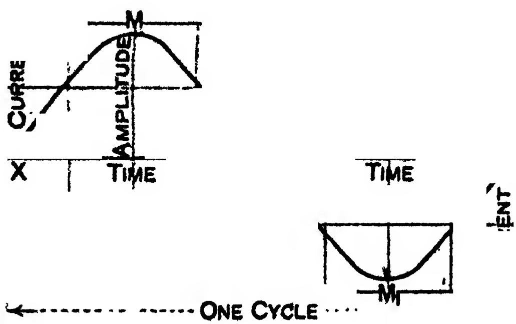

FIG. 37.

round the circuit it reaches a negative maximum at M_1; after which it again falls to zero. A fresh cycle of changes is then commenced. If an ampère meter be included in an alternating-current circuit, its reading, since the current is constantly varying, will be some intermediate value between the limits of the variations. It might perhaps be thought that this reading would be the mean or average value of the current, but this is not the case: the reading shown by the meter is the square root of the mean of the squares of the current. This value is termed the "virtual" value of the current. In the case of the voltmeter the reading

shown will be the square root of the mean of the squares of the volts and the reading will therefore show the "virtual" volts. The term virtual volts or virtual ampères means the value of the direct and continuous voltage or current required to produce an equal effect.

Suppose the ampère meter to be first calibrated by means of a direct current; then if the meter is used on an alternating-current circuit and gives a reading of, say, 100 ampères, that really indicates that the current in the circuit rises to a maximum value of 141·4 amps. and then attains a negative maximum of the same value.

Alternating-Current Dynamo

An alternating-current dynamo consists essentially of a powerful electro-magnet known as the field-magnet, between the poles of which a system of conductors is caused to rotate. Fig. 38 shows a simple alternator, F_1 and F_2 are the poles of the field-magnet, A the armature winding which is caused to rotate, S_1 and S_2 are two metal rings known as the slip-rings insulated from each other and from the shaft on which they are carried, B and B_1 are brushes, which, together with the slip-rings, effect and maintain electrical connection between

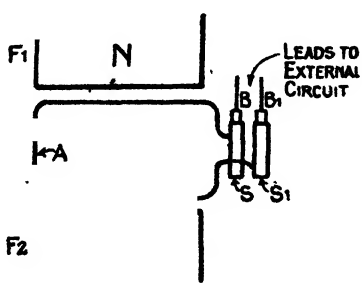

Fig. 38.
Simple alternating-current dynamo.

the armature winding and the external part of the circuit. The field winding is excited by means of a small direct-current dynamo carried on the shaft of the alternator. If a conductor is cut by lines of magnetic force an E.M.F. is induced in it. The induced E.M.F. is proportional to the rate at which the lines of force cut the conductor, and the polarity of the induced voltage is determined by the direction in which the lines of force are cut. Suppose, now, the armature coil P, Fig. 39, to be rotated at a uniform speed between the poles of the field-magnet, the angular velocity will be constant, but the velocity in a horizontal direction will vary. The coil, in turning through the first 30°, has moved in a horizontal direction from 1 to 2 in., turning through the second 30°, it has moved horizontally from 2 to 3, and in turning through the third 30° from 3 to 4. It will

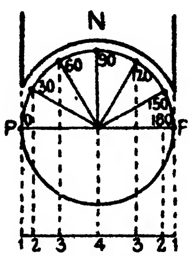

FIG. 39.

be seen, therefore, that the velocity in a horizontal direction increases through the first 90°, diminishes through the second 90°, increases again through the third 90°, and diminishes through the fourth 90°. It will also be noticed that the coil in moving through the second 180° is cutting the lines of force in the opposite direction, the voltage induced in the rotating conductor will therefore be of an alternating nature, changing periodically in magnitude and direction. Fig. 37 shows the variations produced for one complete revolution of the armature coil. If the coil is rotated in a uniform magnetic field, the voltage at any instant is proportional to the sine of the angle through which

the coil has turned. The frequency of an alternator is determined by the number of pairs of poles on the field-magnet and by the number of revolutions of the armature per second. On a two-pole machine, the frequency, therefore, is equal to the number of revolutions per second. By increasing the number of poles on the field-magnet, the required frequency can be obtained with the armature revolving at a lower speed.

For this reason most alternating-current machines have a number of pairs of poles on their field-magnet. In a practical alternating machine, the armature winding is not a simple rectangle of wire as shown in Fig. 38, but consists of a number of conductors, which may be connected either in series or in parallel with each other, and are, of course, wound on a laminated soft iron core. In some machines as, for instance, in that already described, the field-magnet is stationary, and the armature revolves, in other machines the armature is stationary and the field-magnet is caused to revolve. In this case the direct current used to excite it is supplied by means of slip-rings and brushes. The moving part of the machine is termed the rotor, the fixed part the stator. It is usual in machines having a large output, to employ a stationary armature and a rotating field.

Motor-Generator

A motor-generator consists of a direct-current shunt-wound motor, coupled to an alternating-current dynamo. Its purpose in wireless telegraphy is to convert a direct current into an alternating current. The field-magnet of the alternator is excited from the same source of current as that which drives the motor.

Included in the field circuit of the alternator, is a variable resistance, by means of which the alternating voltage can be varied in strength. The addition of resistance in the circuit by weakening the field will, of course, reduce the voltage.

Rotary Converter

Another type of alternating machine frequently met with on wireless installations is the rotary converter. In construction the machine is exactly the same as a direct-current shunt-wound motor, but has, in addition to the commutator, a pair of slip-rings which are connected to two points on the armature winding, 180° apart in the case of a two-pole machine, 90° apart in the case of a four-pole machine. If a direct voltage is applied to the commutator, the armature will rotate, and the armature conductors will cut the lines of magnetic force emanating from the field-magnets, and an alternating voltage will therefore be induced in them. If a circuit is connected across the slip-rings the alternating voltage produced by the rotation of the armature conductors, will set up an alternating current in it.

The voltage at the slip-rings of a rotary converter bears a direct relation to the terminal voltage on the direct-current side. If the voltage across the commutator is, say, 100 volts, the maximum value of the alternating voltage will be 100 also, and the virtual value of the alternating volts will therefore be 70·7, assuming the machine losses to be negligible, and the power factor of the alternating circuit to be unity; the current on the alternating-current side will, since the input and output are equal, be 1·41 times that on the

direct-current side. As an example, suppose the power consumption on the direct-current side to be 1,000 watts, at 100 volts, the current will be 10 ampères. On the alternating-current side the voltage will be 70·7 and the ampèrage 14·1.

ALTERNATING-CURRENT CIRCUITS

Fig. 40 shows an alternating-current circuit having resistance and inductance. The current in a circuit of this kind, will vary directly as the electromotive force and inversely as the impedance of the circuit. Impedance may be defined as the sum total of all the forces opposing the current in the circuit. The impedance is determined by the ohmic resistance and the inductance of the circuit, and by the frequency of the current. The relation between the current, electromotive force and the impedance is shown by the formula $C = \dfrac{E}{\sqrt{R^2 + (2\pi NL)^2}}$ where C equals the virtual amps., E equals the virtual volts, R the ohmic resistance, N the frequency, L the inductance, and π 3·1416. The quantity $\sqrt{R^2 + (2\pi NL)^2}$ is the impedance of the circuit. In an alternating-current circuit, the inductance of which is great compared with its resistance, the controlling factor in determining the strength of the current will be the inductance. Inductance, as we have already seen in a previous chapter, produces a back electromotive force in the circuit,

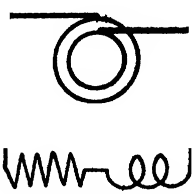

FIG. 40.
Alternating-current circuit having resistance and inductance.

This back E.M.F. is greatest when the rate of change of the current is greatest, and zero when the rate of change of current is zero. The reactive impulses of E.M.F. will therefore be exactly 90° behind the current. To ascertain what voltage is required to produce a current of given strength in an alternating-current circuit having inductance, it is necessary to take into account this back E.M.F. The back E.M.F. or reactive E.M.F., as it is called, due to the inductance of the circuit, is equal to $2\pi NLC$ where N the

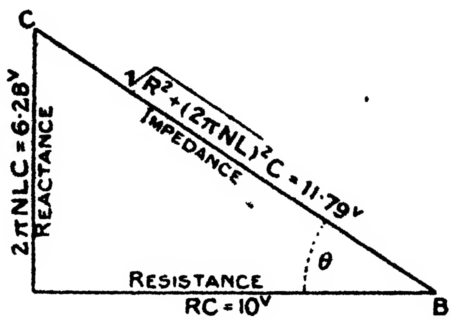

FIG. 41.

frequency, L the inductance of the circuit in henries, and C the current in ampères. As an example, suppose the circuit to have a resistance of 1 ohm, an inductance of ·001 henry, the frequency of the current to be 100, and the strength of the current to be 10 ampères, the reactive E.M.F. will be 6·28 volts approximately. If the circuit were non-inductive, 10 volts would be required to produce a current of 10 ampères, but to produce this current against the reactive E.M.F., will require a greater E.M.F. than 10 volts, but not 10 + 6·28, as the reactive E.M.F. is 90° different in

phase from the current. Let the line A B, Fig. 41, represent the voltage required to produce a current of 10 ampères through a resistance of 1 ohm, and the line A C the voltage required to produce a current of 10 ampères through an inductance of ·001 henry, as this voltage is 90° in advance of the current, the line A C is drawn at right angles to A B. If C and B are now connected, a right-angled triangle is formed, the hypotenuse of which will give the voltage necessary to produce the required current. In the example given,

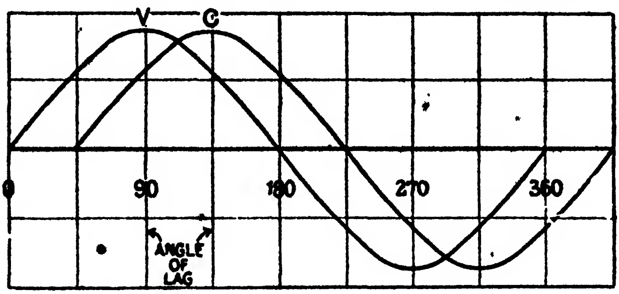

FIG. 42.

Showing lagging due to inductance.

this voltage is 11·79 volts approximately. In a direct-current circuit the power in watts can, since it is the product of volts and ampères, be found by multiplying together the readings of the volt and ampère meters. In an alternating-current circuit having resistance only, the power in watts can be obtained in like manner. If, however, the circuit has inductance, we can no longer rely on the product of the meter readings to give us the power in the circuit. This is due to the fact that the inductance in the circuit produces a back E.M.F., which chokes back the current and so creates a phase difference. In other

words, the ampères will attain their maximum value later than the volts. Fig. 42 shows the lagging effect produced by inductance. The number of degrees through which the armature rotates between the attainment of maximum volts and maximum ampères is termed the angle of lag, and the cosine of this angle is termed the power factor of the circuit. The power in an alternating circuit having inductance is given by the product of volts, ampères, and power factor.

A direct and continuous-current circuit must of necessity consist of a completely closed path of conducting material. In the case of an alternating current, the circuit may consist in part of a condenser, the dielectric of which breaks the metallic continuity. Fig. 43 shows a circuit consisting of a condenser, connected to the terminals of an alternating-current machine. When the machine is started, a current will flow in the circuit until there is a difference of potential at the condenser terminals, equal to the E.M.F. of the machine. When the alternating E.M.F. reverses, the condenser will recharge in the opposite direction. It will be seen, therefore, that although the metallic continuity of the circuit is broken by the condenser dielectric, it is still possible for an alternating current to flow in it. If the capacity of the condenser is small, a small quantity of electricity will be sufficient to charge it to a voltage equal to the E.M.F. of the machine; if the capacity is increased a larger quantity is required to charge it to the same voltage. It will therefore be seen that a condenser in an

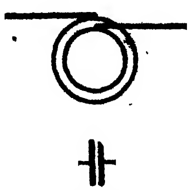

FIG. 43.

alternating circuit reduces the strength of the current, and the smaller the capacity of the condenser the greater will be the reduction in the current strength. As in the case of an alternating-current circuit having inductance, the current will vary inversely as the impedence, which in this case equals $\sqrt{R^2 + (2\pi NK)^2}$ when K equals the capacity in farads. To find what voltage is necessary to produce a current of given strength in an alternating circuit having resistance and capacity, the same procedure as in the case of the inductive circuit may be adopted, that is, the voltage necessary to produce the current through the resistance of the circuit, should be added vectorally to the voltage necessary to produce the current through the capacity reactance, this latter will equal $\frac{C}{2\pi NK}$. Capacity in an alternating circuit produces a phase difference by causing the ampères to attain their maximum value before the volts. When the potential difference at the condenser terminals is zero, the flow of current in the circuit will be greatest, as the condenser charges, a back E.M.F. is produced which lessens the current till, when the condenser reaches a potential difference equal to the E.M.F. of the machine, the current will be zero. As in the case of an inductive circuit, the power will equal the product of volts, ampères, and power factor. Fig. 44 shows an alternating circuit having resistance, inductance, and capacity. The current in such a circuit will vary directly as the

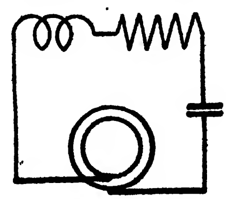

FIG. 44.

E.M.F. and inversely as the imped nce. The impedance in this case will equal $\sqrt{R^2 + \left(2\pi NL - \frac{1}{2\pi NK}\right)^2}$. As before, the voltage necessary to produce a current of given strength can be found by vectorally adding the volts necessary to overcome the resistance of the circuit to the volts necessary to overcome both the inductive reactance and the capacity reactive. As the volts necessary to overcome the inductance reactance are 90° in advance of the current, and those necessary to overcome the capacity reactance are 90° behind the current, the voltage necessary to overcome the total reactance of the circuit will equal $2\pi NLC - \frac{C}{2\pi NK}$. The power in a circuit of this kind will equal the product of volts, ampères, and power factor, and will have its maximum value when the inductance and capacity of the circuit are so proportioned that the inductive reactance equals the capacity reactance. This will be the case when $2\pi NL = \frac{1}{2\pi NK}$, the circuit will then behave as if it had resistance only, and will follow Ohm's law $C = \frac{E}{R}$. When an alternating circuit has been so adjusted that the capacity reactance, exactly equals the inductive reactance, it is said to be in resonance, as the natural frequency of the circuit—given by the formula $\frac{1}{2\pi\sqrt{CL}}$—will equal the frequency of the alternating-current machine. If the capacity is connected to the circuit through the windings of an alternating-current transformer, the

natural frequency of the circuit will equal $\frac{1}{2\pi T\sqrt{CL}}$, where T equals the transformation ratio. This is the case with most wireless transmitters. The circuits are adjusted to resonance by means of an iron-cored variable inductance known as a reactance regulator. If a watt meter is connected in circuit, the attainment of resonance will be indicated by the watt meter giving its maximum reading. The attainment of resonance is also indicated by the volume of sparking at the discharger and by the maximum reading on the aerial ampère meter, the open and closed oscillatory circuits, of course, being in resonance with each other.

Alternating-Current Transformers

In stations intended for long distance working it is necessary to use much larger energies than an induction coil is capable of dealing with; recourse is therefore had to an alternating-current transformer, which can be built for practically any power required. The purpose served is exactly the same as that served by the induction coil, that is, to step up or increase the voltage of the current used to charge the condenser. In construction it is somewhat similar to the induction coil. It consists of a laminated soft iron core on which is the primary winding of large-gauge copper wire. Over the primary winding is the secondary, which consists of many more turns of wire but of smaller gauge. There is no need for an interrupter on the primary circuit, because the current supplied being alternating, the lines of force will cut across the secondary coil as they rise and fall, and an E.M.F.

will be therefore induced in it. The transformer shown in Fig. 45 is known as an open-core transformer, as the magnetic circuit consists partly of the iron and partly of air. Fig. 46 shows a closed-core transformer, the magnetic circuit consisting of a completely closed path of magnetic material. The closed-core type is preferable, as there is less magnetic leakage than with the open-core type. *The magnetic leakage can be* still further reduced by making the core a long rectangular shape (Fig. 46), and winding the coils on the longer limbs. The leakage path is chiefly from one end of the coil to the other, and by lengthening it, its magnetic reluctance is increased and the leakage consequently reduced. The ratio of the voltages at the terminals of the primary and secondary windings will be equal to the ratio of the number of turns on the two windings. Whatever the ratio of the voltages, the currents will be approximately in inverse ratio, as apart from the transformation losses, the input and

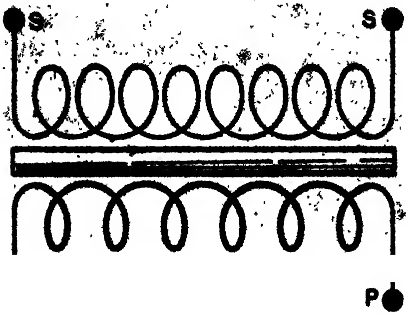

FIG. 45.

Alternating-current transformer.

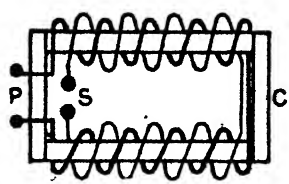

FIG. 46.

Transformer with closed core.

output reckoned in watts will be equal. As an example, suppose there are 100 times as many turns on the secondary as there are on the primary, then the voltage at the secondary terminals will be 100 times as great as the voltage at the primary, and the current in the secondary will be approximately $\frac{1}{100}$ of the primary current.

If no current is taken from the secondary winding, the primary acts almost entirely as a choking coil, only allowing sufficient current to flow, to produce the necessary magnetic field and to supply the power absorbed in the winding and the core. When the secondary circuit is completed, and current taken from it, the magnetic flux cutting the primary is reduced—as the secondary current is flowing in the opposite direction to the primary current—and the back E.M.F. produced by it is lessened, thereby allowing a greater current to flow in the primary circuit. As the secondary current increases, so will the primary current increase. A small transformer may be air cooled, but larger transformers are usually immersed in oil in order to prevent an undue rise in temperature and to improve the insulation of the secondary winding. For the purposes of wireless telegraphy it is usual to supply current at from 100 to 500 volts, and to step it up to 20,000 or 30,000 volts.

Meters

The Voltmeter, The Ampère Meter, The Watt Meter, The Frequency Meter

A voltmeter is, essentially, a galvanometer so constructed that the scale readings are proportional to the difference of potential between the two points of

the circuit to which it is connected. To effect this, it is essential that the resistance of the instrument should be so great, that the internal resistance of the battery or dynamo, whose voltage it is required to measure, shall not appreciably affect the strength of the current passing through it. As an example, if a galvanometer having a resistance of, say, 5 ohms, is connected across the terminals of 100-volt dynamo, having an internal resistance of 2 ohms, the current passing through it will be 14·28 amp. (approx.). Now suppose the galvanometer is connected across the terminals of a 100-volt machine having a resistance of 5 ohms, the current will be 10 amp. and the deflection of the needle much less, though the voltage of the dynamo was the same in the two cases. Now suppose the galvanometer resistance to be increased to 500 ohms, the strength of the current will be ·199 amp. approx. in the first case, and ·197 amp. approx. in the second case. As the currents are practically equal, the deflections of the galvanometer needle will also be equal. A voltmeter is always connected as a shunt across the two points, whose difference of potential it is required to measure, Fig. 47.

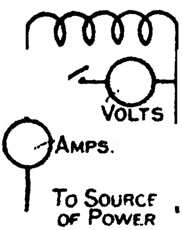

FIG. 47.

Construction of Voltmeters

Volt and ampère meters may be classified according to their principle of action, or according to the class of circuit, on which they can be used. Classifying according to principle of action, we have electro-magnetic instruments, thermal instruments, electro-static

instruments, and induction instruments. It is proposed here only to describe the hot wire meter, and the moving coil meter, both of which are suitable for use on an alternating as well as on direct-current circuits, and frequently form part of a wireless installation.

The Hot Wire Voltmeter

This instrument consists of a fine platinum wire, stretched between two terminals, to the centre of the wire is attached another very fine wire of phosphor bronze, the other end of which is fixed. To the centre of this second wire a silk thread is connected, which passes round a pulley on the spindle of the pointer and is then attached to a spring. When current passes through the platinum wire its temperature is raised, and owing to the expansion of the wire a sag is produced, the sagging of the wire enables the spring to move the pointer. The pointer is prevented from oscillating by an aluminium disc carried on the spindle and moving between the poles of a permanent magnet. As this instrument depends for its action on the heating effect of the current, the scale will not be evenly divided. The heat produced varies as the square of the current, the divisions on the scale will therefore be proportional to the square of the current passing through the wire. An adjusting screw is provided by means of which the pointer can be brought exactly to zero. As the resistance of the platinum

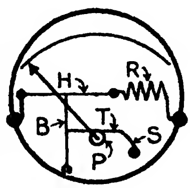

FIG. 48.
Hot wire voltmeter

H. Platinum wire.
B. Bronze wire.
T. Silk thread.
P. Pulley.
S. String.
R. Resistance.

wire is of itself insufficient, a high non-inductive resistance is connected in series with it, this resistance is sometimes incorporated in the instrument itself, and sometimes supplied as a separate unit. If a voltmeter is left permanently connected to the circuit, a certain amount of power is consumed by it. To prevent this it is usual to provide a switch, the closing of which will enable a reading to be taken, the switch being open at all other times.

The Moving Coil Voltmeter

This instrument consists of two coils each of a few turns, connected in series with each other. One coil is fixed, the other coil is capable of rotation, and in the zero position is at right angles with the fixed coil. If, now, current passes through the coils, the magnetic fields built up around each of them tend to turn the moving coil, till its winding is parallel with that of the fixed coil. The twisting force exerted by the magnetic field is acting against a spiral spring, which brings the needle back to zero when the current ceases to flow. The usual high non-inductance resistance is connected in series with the coils, and as the reactance is small compared with the resistance, it can be used on an alternating as well as on a direct-current circuit.

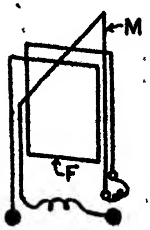

FIG. 49.

Working part of moving coil meter.

F. Fixed coil.
M. Moving coil.
The indicating needle is carried on the spindle of the moving coil.

Ampère Meters

An ampère meter is essentially a galvanometer, whose scale has been so graduated that the pointer

moving across it indicates the strength of the current flowing in the circuit directly in ampères. An ampère meter is connected directly in the circuit, and for this reason its resistance must be kept at a low value. The working part of the instrument has, connected in parallel with it, a conductor of low resistance, so that only a small, but known fraction of the current passes through it. This low resistance conductor is known as a shunt. As in the case of voltmeters, ampère meters may be classified according to their principle of action, or according to the class of circuit on which they can be used.

The Hot Wire Ampère Meter

The working part of the hot wire ampère meter is, in construction, exactly the same as the hot wire voltmeter. Connected across its terminals is the low-resistance shunt through which the greater part of the current passes, only a small known fraction passing through the platinum wire. Fig. 47 shows how the instrument should be connected in circuit.

Moving Coil Ampère Meter

The working parts of this instrument are exactly the same as the working parts of the moving coil voltmeter. As the total resistance of the coils is low, and the gauge of the wire used sufficiently large to carry the whole current, the shunt is dispensed with.

The Watt Meter

In a direct-current circuit the power in watts can, since it is the product of volts and ampères, be obtained by multiplying together the readings on the volt and

ampère meters. The power may, however, be read directly, providing an instrument known as a watt meter is connected to the circuit. In the case of an alternating-current circuit, the use of a watt meter is essential, as the product of the volt and ampère meter readings will be in excess of the true power, as most usually some phase difference exists between the volts and ampères. In construction a watt meter is similar to the moving coil instrument already described, except that the coils are not in the same circuit. The fixed coil is connected in series in the circuit, and therefore carries the whole current, the moving coil is connected in series with a high non-inductive resistance and the two are then bridged across the circuit in the same way as a voltmeter, owing to the high resistance, the current in this coil is proportional to the volts. The passage of a current through the two coils will build up a magnetic field about each of them, and the movable coil will tend to turn so that its winding becomes parallel with that of the fixed coil. Suppose, now, that the alternating circuit has been adjusted to resonance, the volts and ampères will be in phase with each other, and the current in the two coils will reach their maximum values at the same time. The maximum twisting force is therefore exerted on the movable coil, and the indicating needle will give the largest scale reading. Suppose now that there is

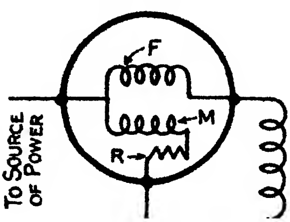

FIG. 50.
Showing method of connecting watt meter to circuit.

F. Fixed Coil.
M. Moving coil.
R. Resistance.

a phase difference of 90° between the volts and ampères, when the current in one coil is at its maximum value, the current in the other coil will be at zero, consequently, as no twisting force is exerted on the movable coil, the indicating needle will not be displaced. For any phase difference between 0 and 90 the deflection of the needle will be proportional to the product of volts, ampères, and cosine of angle of lag, and the true power in the circuit is therefore indicated. Fig. 50 shows the method of connecting a watt meter to the circuit.

The Frequency Meter

The frequency of an alternator is determined by the speed of its armature and the number of pairs of poles on its field-magnet. If means are available for ascertaining the speed of the armature per second,

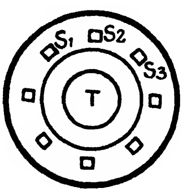

FIG. 51.

T. Top of magnet.
S_1, S_2, S_3. Reeds.

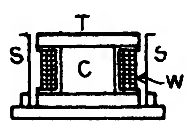

FIG. 52.

T. Top of magnet.
C. Core.
W. Winding.
S. Reeds.

the frequency can be found by multiplying the pairs of poles. The frequency can, however, be read directly if an instrument known as a frequency meter is connected in circuit. The meter consists of an electromagnet, having a well-laminated soft iron core, and a high resistance winding. Fig. 51 shows the magnet

in plan and Fig. 52 in section. A number of soft iron strips, or reeds are arranged round the magnet, their ends being in close proximity to the pole of the magnet. Each of these reeds are so constructed as to vibrate to a certain definite frequency, much as do the prongs of a tuning-fork. Suppose now an alternating current to pass through the coil, the iron core is magnetised in one direction by the first half-cycle of current, and in the opposite direction by the second half of each cycle of alternating current, in either case an attractive force is exerted on the reeds and they are attracted towards the magnet. The reed, whose frequency is the same as that of the current impulses passing through the magnet coil, will, by the action of resonance, attain a much greater amplitude of vibration than one whose frequency is different. Generally, the reeds on either side of the resonant reed, will be in vibration, as their frequencies are not very different, but the amplitude attained by them is noticeably less, while those having considerably different frequencies are quiescent. The instrument is connected to the circuit in the same way as a voltmeter.

MOTOR-STARTING SWITCH

The resistance of the armature winding of a motor is low, and if the full voltage of the supply mains were applied to it while at rest the result would be that the insulation would be destroyed, owing to the heating of the conductor by the very large current which would pass. When the motor is running an E.M.F. is set up due to the fact that the armature coils are revolving in a magnetic field; the E.M.F. so generated

is in opposition to that of the supply mains and the total E.M.F. acting on the armature is therefore the difference between the two. It is therefore necessary during the time the motor is starting to place a resistance in series with the armature winding to keep the current through it low. This is done by means of a piece of apparatus known as a starting switch.

The starting switch (Fig. 53) performs the following

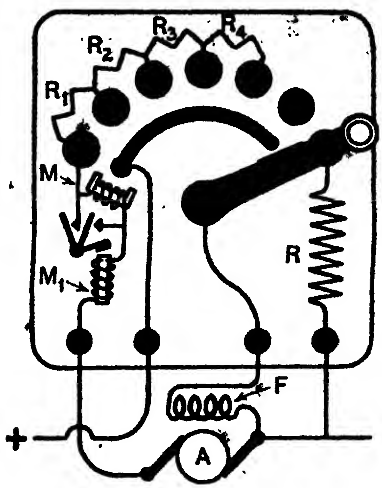

FIG. 53.
Motor starting switch.

operations and in the order named. When moved from its position of rest it first makes contact with a segment which completes the circuit through the field coils, which are then fully excited, it next closes the circuit through the armature of the motor, the starting resistances being in series with it. As the motor gathers speed the switch arm is moved further round,

and the resistance diminished step by step until, when the motor has attained its maximum speed, they are finally cut out altogether. In starting the motor, the switch should only be kept on each segment long enough for the motor to attain its top speed for that segment and then moved on to the next. If this is not done, and the arm is kept too long on one segment, it may result in the heating up of the starting resistances. Referring to the diagram, M is an electro-magnet whose coil is included in the main circuit, the function of this magnet is to hold over the arm of the switch while the motor is running, and if from any cause the supply current is cut off from the mains the arm will be released, and by the action of a spring will be carried to the off position. The motor will thus be protected from the damage that would occur if it had come to rest and the supply current was switched right on the armature without the starting resistance being in series with it. M_1 is also an electro-magnet whose coil is included in the main circuit. The function of this coil, which is termed an overload release, is to automatically cut off the supply current should it from any cause rise to dangerous proportions; it does this in the following way. The coil is furnished with an armature so arranged that the normal current flowing through the coil is insufficient to attract it, but if the current is increased beyond a certain value the armature will be pulled down and when in this position will short-circuit the coil of the magnet M, and the switch arm being thus released will move over to the off position.

Referring again to the diagram, F is the field-magnet coil, A the armature of the motor, R_1, R_2, R_3,

and R_4 the starting resistances, and R is a resistance about equal to the field-magnet coils. It will be seen that when the motor is stopped the arm of the switch in moving back to its position of rest will put this resistance in parallel with the field coils before their circuit is broken, the function of the resistance being to take up the current induced by the opening of such a highly inductive circuit as the field-magnets; if this precaution were not taken it is probable that the insulation of the field-magnet coils would be damaged.

CHAPTER III

THE RECEIVER

Arrangement of Receiving Circuits—Construction of Tuners—Wavelength Range of Tuners—Protective Devices

In the earlier forms of receiver the detector was inserted directly in the base of the aerial. With such an arrangement, owing to the damping of the oscillations by the detector, little use could be made of resonance and the detector would be actuated by oscillations of any frequency which were in the aerial.

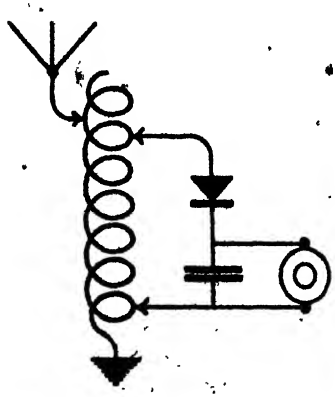

FIG. 54.

Circuits of directly coupled receiver.

The present-day practice is to place the detector in a subsidiary circuit which is either directly or inductively coupled to the aerial circuit. The arrangement of the circuits when direct coupling is used is shown in Fig. 54. The tuner consists of a former of some insulating material wound with insulated copper wire, the insulation of the wire being removed for a small space on each turn to enable metallic connection to be made by a sliding contact. The tuning is effected by varying the amount of the inductance in the aerial circuit and the coupling of the detector circuit is also

varied by means of the sliding contacts, the position of which determine how much of the inductance is common to both circuits.

Such an arrangement has the merit of simplicity inasmuch as there is only one variable and if the coil is of fair size a large range of wave-lengths can be covered. In actual use it has been found that the sliding contact is apt to become dirty and make indifferent contact with the coil, which by introducing resistance increased the damping, and thereby weakens the signals.

When using a tuner of this kind it is not possible to get very fine tuning, but as a call-seeking device, or where by reason of inability to secure highly skilled operators extreme simplicity is necessary, it has its advantages.

The method of inductive coupling is the one most generally used, the tuners usually consist of three circuits, a primary or aerial circuit, a secondary circuit which is tuned to the primary and coupled to it and a tertiary circuit which is untuned and contains the detector.

The coils for such a tuner should preferably be laminated—that is to say, instead of using a solid copper wire a conductor built up of a large number of very small insulated wires laid side by side, should be used. The reason for this is that when a conductor is traversed by high-frequency currents, the current tends to confine itself to the surface and penetrates to no appreciable depth; the resistance of the wire is therefore many times higher for currents of high frequency than for steady currents. As, however, a conductor built up of many insulated strands has a

very large surface, the difference between its resistance to high-frequency currents and its resistance for steady currents will not be great, as would be the case with a solid conductor whose surface is small compared with its cross-section. It is also advisable that the coils should not be too closely wound, as close winding tends to confine a high-frequency current to a

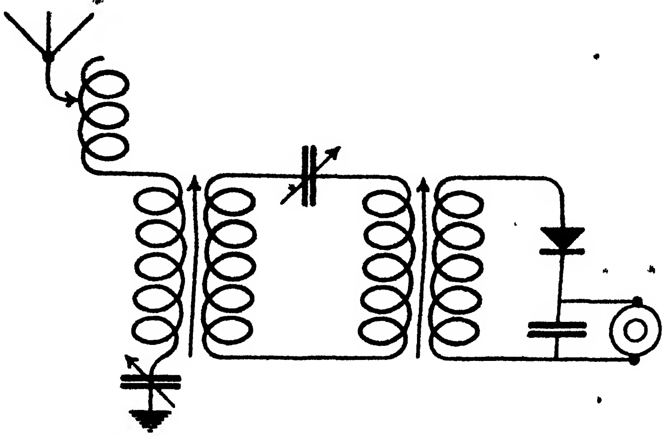

FIG. 55.

Circuits of inductively coupled tuner with intermediate circuit.

certain part of the surface of the wire, and this also, it will be seen, would still further increase the resistance. Fig. 55 shows diagrammatically the arrangement of an inductively coupled tuner. As will be seen, the tuning of the primary circuit is effected by means of the variable inductance and the variable condenser which are in series with the aerial. The object of providing both a variable inductance and a variable condenser in this circuit is to enable the operator by means of the inductance, to tune in wave-lengths

greater than the natural wave-length of the aerial, and by means of the condenser to tune in wave-lengths shorter than the natural wave-length of the aerial.

The secondary or intermediate circuit is a closed and feebly damped circuit. It consists of inductance and capacity in series, the condenser being variable. (In the diagram the inductance is shown as consisting of two coils; this need not be, and in fact very often is not the case, but is so shown simply to make the diagram clearer.)

The tertiary circuit consists of the coil fixed capacity and the detector. The function of the condenser in this circuit is to act as a shunt to the telephone, which by reason of its high self-inductance would act as a choking coil and prevent oscillations from being set up in the circuit. The capacity of this condenser to produce the best results will depend upon the resistance and inductance of the telephones and also on the spark frequency of the transmitter. Generally speaking, if high-resistance telephones are used, the capacity of the condenser is small, and if low-resistance telephones are in use the capacity will be greater. In some installations the capacity of this condenser is variable in steps, but the optimum value is not very sharply marked.

The action of the tuner is as follows. On the primary circuit being tuned to the transmitter from which it is desired to receive signals, oscillations are set up in it, and the primary acting inductively on the secondary which is loosely coupled to it, passes the oscillations on; the secondary circuit in turn acting inductively on the detector circuit. It will be seen

that if the coupling is very loose no considerable effect can be produced in the secondary circuit except by resonance and it must therefore be exactly in tune with the primary. Any oscillations of different period that may exist in the aerial circuit will not be passed on to the secondary and so are prevented from actuating the detector. The rejection of signals not absolutely in tune is one of the chief advantages of the inductively coupled tuner, as considerable interference

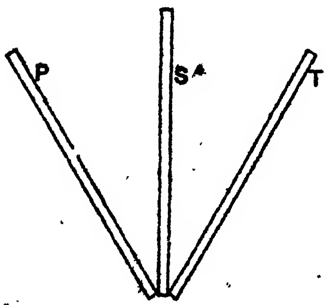

FIG. 56.

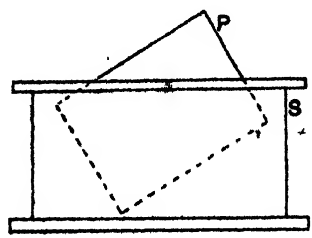

FIG. 57.

from neighbouring stations working on only slightly different wave-lengths is avoided. In actual practice the tuners take different shapes, in some the coils are mounted on a rod on which they can slide and the coupling varied, by varying the distance between them. In others the coils take the form of flat spirals mounted on sheets of ebonite which are hinged together like the leaves of a book and the coupling varied by opening or closing the leaves (Fig. 56). In the most practical form the tuner consists of two coils placed one within the other, the inner one being so arranged that its plane can be turned through an angle of 90° and

the coupling thus varied (Fig. 57). The tertiary in this case is not a separate coil, but is formed by tapping off a few turns of the secondary (Fig. 58).

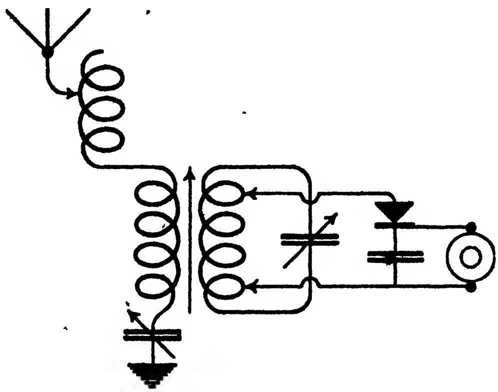

FIG. 58.

WAVE-LENGTH RANGE OF TUNER

The wave-length range of a tuner is determined by the variability of the capacity and the inductance of its circuits. As regards the aerial circuit of a tuner, it is usual to make provision for varying both the inductance and the capacity of the circuit, but in the case of the intermediate and detector circuits the wave-length range is usually extended by the connection in series, and in parallel, with the variable condenser, other condensers of fixed capacity. Take, for example, a tuner circuit having an inductance (non-variable) of 28,000 cms. and a capacity variable between ·001 of a mf. and ·01 mf., the wave-length range would approximately be 100 to 1,000 meters. Now suppose it is desired to tune in wave-lengths as

low as 50 meters from the formula $\lambda = 59{\cdot}6\sqrt{CL}$, it is evident that the capacity of the circuit must be reduced to ·00026 mf., this can be done by connecting a condenser having a capacity of ·00034 (approx.) in series with the variable condenser, if this latter is then adjusted to its lowest value (·001), the circuit will be tuned to a 50-meter wave-length.

Now supposing that it is desired to tune in wave-lengths greater than 1,000 meters, a condenser having a capacity equal to the maximum capacity of the variable condenser must be connected in parallel with

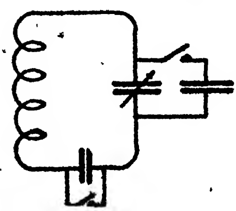

FIG. 59.

Series condenser in use for short wave-lengths.

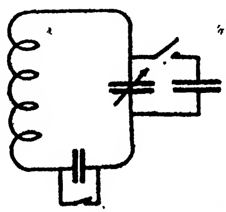

FIG. 60.

Series condenser sharded.

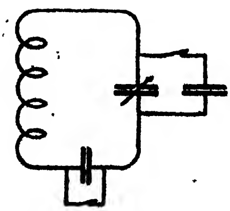

FIG. 61.

Parallel condenser in use.

it, this will bring the upper wave-length limit to 1400 meters (approx.), additional condensers may be connected, and the wave-length range so extended until the desired range is obtained. A good example of this method of extending the wave-length range is the Marconi Multiple Tuner described in Chapter VI. The parallel condensers usually have a somewhat smaller capacity than the maximum value of the variable condenser to avoid any break in the wave-length range. In the case of the detector circuit of a tuner intended for use with a potential actuated device, such as a

carborundum crystal, the wave-length range of the circuit is usually extended by the addition of inductance to the circuit. This method prevents the reduction of the terminal voltage of the condenser, which would follow if the capacity of the circuit were increased by the addition of another condenser in parallel.

Protective Devices

When the transmitter is in use, it is necessary that the detector should be protected from the comparatively heavy currents set up in the circuits of the receiver by reason of their proximity to the transmitter. There are a number of methods of doing this. In the case of the Marconi coherer set a long-arm switch is arranged at the side of the Morse key, which, when down or in the send position, completes the power circuit by connecting two contacts which otherwise form a break in the circuit, and at the same time by means of a cord passing over a pulley fixed in the ceiling above, it lifts the aerial rod from its socket and so isolates the coherer. It will thus be seen that the connection of the aerial to the receiver necessitates the opening of the power circuit, and should the Morse key be accidentally depressed the coherer will be uninjured, as no current is supplied to the transmitter; also it will be seen that before the transmitter can be brought into use the arm of the switch must be lowered to short the break in the power circuit, and that this cannot be done without at the same time disconnecting the aerial from the receiver.

In other systems protection is afforded to the detector either by providing it with a low-resistance non-inductive shunt, or else by breaking the circuit in which it

is situated. The usual method of doing this is by means of auxiliary contacts on the switch used to change the aerial from the transmitter to the receiver, so arranged, that when the aerial switch is over to send, the detector is either short-circuited or its circuit broken; and when it is in the receive position the short-circuit is removed or the circuit completed, while the power circuit is broken. The method of breaking the detector circuit is the more usual and also the more satisfactory of the two, as it is difficult to provide an efficient shunt for the detector owing to switch near enough to the detector to avoid the use of long wires.

Lightning Protectors

That part of the tuner which forms part of the aerial circuit is protected from lightning, or any suddenly-applied high voltage, by means of a finely-adjustable spark-gap connected between the aerial and earth terminals of the tuner. Should the aerial be struck by lightning, the gap is bridged by the spark, thus completing a path of low self-inductance to earth, through which the discharge can pass without damage to the working parts of the primary circuit. If the tuner is connected across an earth arrester spark-gap, an additional spark-gap on the tuner is superfluous, as the earth arrester gap performs its function.

Prevention of Atmospheric Charges on the Aerial

The metallic continuity of the aerial circuit of the receiver is, in most cases, broken by the dielectric of a condenser, connected in series in order to obtain

wave-lengths less than the natural wave-length of the aerial. An electro-static charge can therefore be retained and may be of such magnitude as to puncture the dielectric of the condenser, or should the aerial be touched by the operator he may experience a severe shock. To prevent the accumulation of these atmospheric charges, a metallic path between aerial and earth must be provided. This metallic path consists of a coil having great self-inductance, the purpose of giving it great self-inductance being to prevent the diversion of the received oscillations from the working part of the primary circuit. A conductor having great self-inductance will choke high-frequency currents.

CHAPTER IV

DETECTORS OF ELECTRICAL OSCILLATIONS

Marconi Coherer Receiver—Lodge Muirhead Coherer—Electrolytic Detector—Carborundum Detector—Fleming Valve—Thermo-Electric Detectors—Magnetic Detector—The Telephone Receiver.

THE detectors used in Radio-Telegraphy may be broadly divided into two classes: those that are potential actuated and those that are current actuated: the former are always joined across the terminals of the condenser, as the potential differences are largest there, and the latter or current-actuated variety are connected in series with the condenser. Detectors may also be further subdivided into classes—namely, imperfect contact devices, such as the Marconi coherer; rectifying devices, such as the Fleming valve and the carborundum detector; electrolytic detectors, as those of Fessenden and Schlomilch; the thermo-electric type, formed of galena against graphite, and various other combinations, and those that depend for their action on the alteration of their magnetic properties: in this class is the Marconi magnetic detector.

THE COHERER

The coherer, which is the result of the work of many men—Hughes, Lodge, Branley and Popoff among others—consists essentially of a small quantity of metal filings lying loosely between metallic electrodes. The first practical form of the device for telegraphic

purposes was brought out by Marconi, and consisted of a very small quantity of nickel filings, to which were added a small percentage of silver filings, lying between silver electrodes having bevelled ends so that the space between them, in which were the filings, was wedge-shaped.

The purpose of thus bevelling the plugs is to enable the sensitiveness of the coherer to be adjusted. The most sensitive position is when the nose of the wedge is pointing downward and the reverse position is that of least sensitiveness.

FIG. 62.

Marconi coherer.

The plugs and filings are enclosed in a glass tube, which is exhausted to a partial vacuum, and the wires connected to the plugs pass out through the ends of the tube (Fig. 62).

The coherer depends for its action on the fact that, if its terminals are subjected to a potential difference above a certain value, the resistance due to the loose contact between the filings and plugs suddenly falls to a much lower value; some investigators think that ordinary electro-static attraction is a sufficient explanation of its behaviour, others hold that microscopic sparks pass between the filings and slightly weld them together; however this may be, the fact remains that, after being subjected to the potential differences set up by the oscillations, the resistance falls

enormously, and if the coherer is joined up with a relay and cell, and the relay contacts joined up with a Morse writer and battery, the passage of electrical oscillations will be made evident by the closing of the relay circuit and consequent recording of signals. As, however, the coherer will not of itself resume its former high resistance a small electro-magnetic hammer is provided to tap gently on its under side, and

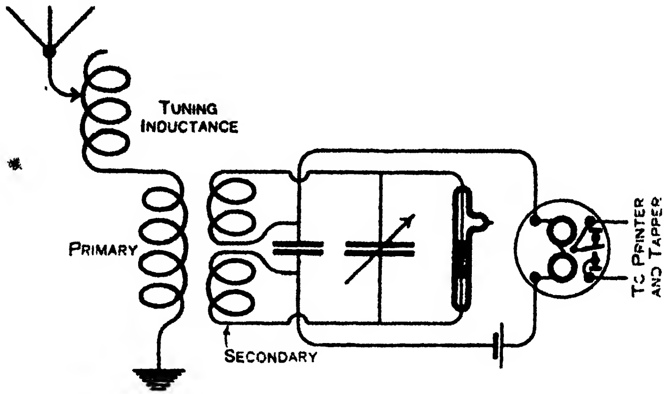

FIG. 63.
Circuits of Marconi coherer receiver.

by shaking the filings loose it restores the coherer to its high resistance and again renders it sensitive to oscillations.

Fig. 63 shows the circuits of the Marconi coherer receiver. The aerial circuit consists of tuning inductance and primary of oscillation transformer joined in series and connected to aerial and earth. The secondary winding of the oscillation transformer is cut in the middle but its continuity for electrical oscillations is preserved by the insertion of a condenser. To the ends of the secondary winding is connected a

variable condenser for tuning it to the primary and across this latter is the coherer.

The relay with a single dry cell in series is connected across the condenser inserted in the break of the secondary winding. To the contact terminals of the relay are joined a battery of cells in series with the Morse printer, and in parallel with the printer is the tapper, the function of which is to shake loose the filings in the coherer after it has been actuated by the oscillations.

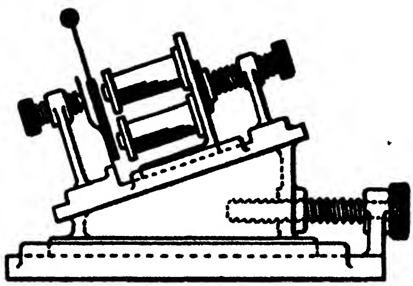

FIG. 64.

Marconi decoherer.

Owing to the high self-induction of the relay, printer, and tapper coils, it is essential that they and also the contacts of the relay and tapper should be shunted by high non-inductive resistances to eliminate the sparking which would otherwise occur and which, though small, would be sufficient to actuate the coherer.

The adjustment of the various circuits and pieces of apparatus comprised in the above-described set is usually thought to be a difficult matter, but if it is systematically done it will be found fairly simple. The operator should proceed as follows: first, by means of the adjusting screw set the magnet of the tapper as far away from its armature as is possible, then adjust the knob of the tapper so that it is at the distance of about one millimetre from the coherer. The next step

is to turn the adjusting screw of the relay till the local circuit closes and then to slowly turn it in the reverse direction till it just opens. Test letters should now be sent on the buzzer (the buzzer is a small trembler movement worked by a dry cell and constitutes a generator of feeble electrical oscillations), and at the same time the magnet of the tapper made to gradually approach its armature till the strength of the beat is sufficient to give good sharp signals on the Morse printer.

If the beat is too weak the signals will tend to run together, and if it is too strong they will be cut up—that is to say, the dashes will appear as a series of dots. The whole of the apparatus above described, with the exception of the printer, is enclosed in a metallic box to prevent damage to the coherer from the powerful oscillations which would be set up in the circuits when the transmitter was in use.

Lodge-Muirhead Coherer

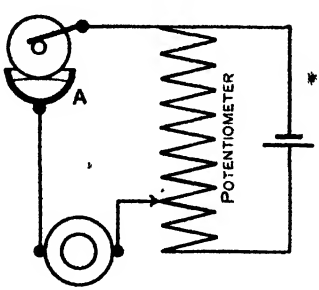

Fig. 65.
Lodge-Muirhead coherer.

This coherer, which may be used either with a telephone or with a syphon recorder, is constructed as follows: a small metallic cup A (Fig. 65) contains a globule of mercury on which is placed a small drop of oil, which forms an infinitely thin insulating film over it; above the globule of mercury is a small iron disc with a sharp edge and which is slowly rotated. By means of an adjusting screw the lower edge of the

disc is made to touch the oil-covered mercury, but the pressure is not so great as to puncture the film of oil. In series with the coherer is joined a dry cell and telephone receiver, or syphon recorder, as the case may be, and the passage of electrical oscillations, by breaking down the insulating film of oil, allows the cell to operate the receiving instrument. This form of coherer is self-restoring and needs no tapping arrangement.

Electrolytic Detector

This detector consists of a platinum cup containing a solution of dilute acid. The cup forms one electrode and the other consists of a wollaston wire sealed into a glass tube, which is drawn out very fine and then broken off, leaving only the cross-section of the wollaston wire exposed. Connection is made to the wire by means of the metal tube in which the electrode is mounted. The detector with high-resistance phones in series with it is tapped across two points of a potentiometer which has a battery across its terminals. The small current which passes through the detector polarises it—that is to say, gas is formed at the electrodes and the resistance thereby materially increased. If now the arrangement be subjected to the small alternations of potential and current set up in a receiving circuit by the impact of electrical oscillations it will be depolarised, and the resistance of the electrolytic cell falling, a small current will pass through the phones and will be audible to the operator; after the arrival of each wave train the battery again polarises the cell, the device being thus self-restoring. To adjust the cell, the small electrode having been inserted in the holder and its point dipping into the

electrolyte, the arm of the potentiometer is moved round till a hissing noise is heard in the phones, it is then moved back until the noise just ceases. The detector is then in its most sensitive condition. This form of detector is in extensive use, and is very sensitive and reliable; it has been found, however, that atmospheric disturbances, if at all strong, render the device insensitive, but not permanently so, as it restores itself in the course of a few seconds. The restoration may be accelerated by momentarily increasing the voltage across its terminals by moving the arm of the potentiometer round a little. Fig. 66 shows the wollaston wire electrode.

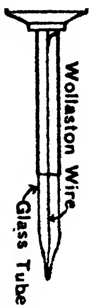

FIG. 66.

CARBORUNDUM DETECTOR

The carborundum detector is very simple in construction, and may consist simply of a small carborundum crystal held between two brass springs. It works by virtue of the fact that carborundum has what is termed unilateral conductivity. Supposing a crystal of carborundum be joined in series with a battery and galvanometer and the current noted, and the poles of the battery reversed and the current again noted, it will be found that the two currents differ greatly although the electromotive force of the battery remained unaltered. This shows that for currents in one direction carborundum has a very high resistance and is practically an insulator, but for currents in the reverse direction it is comparatively a good conductor. It will thus be seen that a crystal of carborundum can

act as a rectifier and change an oscillatory or alternating current into a direct current. Many crystals beside carborundum possess an unilateral conductivity, but not in such a marked degree. It has also been found that for certain voltages the unilateral conductivity of the crystal is greater than for others. Fig. 67 shows the characteristic curves of a metallic conductor and a carborundum crystal, and will perhaps make the matter plain.

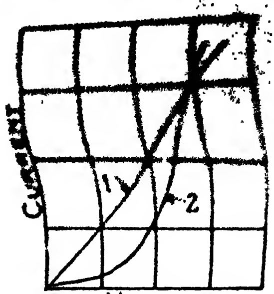

FIG. 67.

Curve 1 shows the relation between the voltage applied to a metallic conductor and the current produced in it. The current, it will be seen, varies directly as the voltage. Curve 2 shows the relation between applied volts and the current produced in a circuit containing a carborundum crystal. The current in this case is not directly proportional to the volts, it will be seen that it increases slowly as the voltage is increased, up to a certain point, after which the curve becomes much steeper, showing that a slight increase in voltage after the optimum voltage has been reached, causes a relatively large increase in the current passing through the crystal. The optimum voltage is applied to the crystal by means of a battery

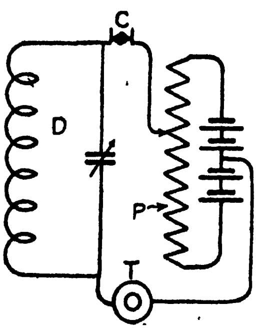

FIG. 68.

C. Crystal.
P. Potentiometer.
T. High resistance telephones.
D. Detector circuit of tuner.

of cells and a potentiometer. If now, the crystal is subjected to small oscillatory differences of potential, as it is when signals are received from a distant transmitter; that half of each cycle which is acting in the same direction as the cells will cause a relatively large increase in the current passing through the crystal and through the telephone receiver connected to it. That half of each cycle which is acting in opposition to the cells will cause the crystal current to be diminished. The carborundum detector has a very high resistance, high-resistance telephones should therefore be used, but low-resistance telephones may be used if connected to the circuit through the windings of a step-down transformer. To prevent too rapid a discharge of the cells, the potentiometer across which they are connected should be of comparatively high resistance, say, 500 ohms. It will be noticed that connection is made to the middle of the battery and not to one of the end terminals, this arrangement enables the direction of the current through the crystal to be changed without disconnecting the cells.

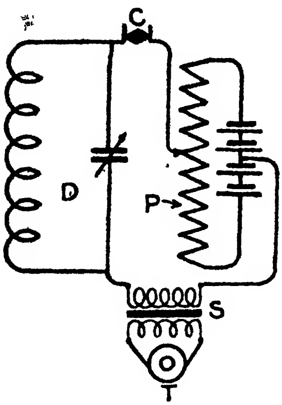

FIG. 69.
Carborundum crystal receiver using low resistance telephones and step-down transformer.
S. Step-down transformer.

FLEMING VALVE

The Fleming valve detector consists of a carbon or tungsten filament lamp, in the bulb of which is also

included a metal plate insulated from the filament, and the connecting wire of which is brought through the glass wall of the bulb to a third terminal outside. If the filament be rendered incandescent by the application of a suitable battery to its terminals, the space between the filament and the insulated plate will be found to possess an unilateral conductivity, and if it be now connected to a circuit in which oscillations are taking place, it will, by its rectifying action, convert them into unidirectional impulses capable of actuating a telephone receiver. As with the carborundum detector, the application of a local voltage increases the sensitiveness of the detector. The necessary voltage is applied and regulated by means of a battery of cells and a potentiometer, the arrangement of the circuit being as shown in Fig. 70.

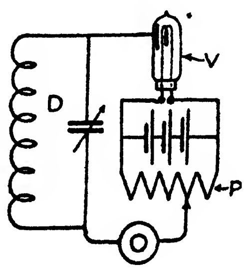

FIG. 70.

Fleming valve detector.

V. Value.
P. Potentiometer.
T. High resistance telephones.
D. Detector circuit of tuner.

The resistance of the ionised gas between the filament and the plate is very high. To obtain best results, the telephone receiver should therefore be wound to a high resistance, about 4,000 ohms. Low-resistance telephones may be used provided they are connected to the circuit through the windings of a step-down transformer (Fig. 69).

Fig. 123, Chapter VI, shows the valve tuner of the Marconi Company, it will be noticed that the bulb of the valve is surrounded by a copper gauze, the purpose of this is to prevent static charges of electricity

from accumulating on the glass, as the detector is rendered insensitive by them. The gauze screen is connected to earth. Another type of valve detector recently brought into use by the Marconi Company has a third electrode, which takes the form of a perforated metal plate or grid, and is interposed between the filament and the plate. The grid and the plate are both cylindrical in shape and nearly enclose the filament, thus preventing the detector from being made insensitive by electro-static charges on the glass of the bulb. The circuits may be arranged as shown in Fig. 71, where P is the plate, G the grid, F the filament, and T the telephone receiver, which is of high resistance. B_1 is the battery supplying current to the filament, and B_2 is a battery of about 50 volts, connected on one side through the telephone receiver to the insulated plate and on the other side to the filament.

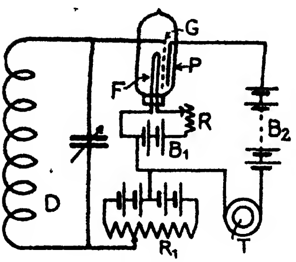

FIG. 71.

Three electrode valve.

P. Plate. G. Grid.
F. Filament.
T. Telephone receiver.
R. Regulating resistance.
R_1. Potentiometer.
B_1. B_2 batteries.

The conductivity of the gas between the filament and plate is found to vary as the potential of the grid is varied, thus, while the grid is at zero potential, there is a steady flow of current from the battery B_2 through the telephones to the plate across the gas to the filament and so back to the negative pole of the battery. When oscillations are set up in the detector circuit, the grid, which is connected to it, will be subjected to alternating differences of potential, if the

grid is charged to a positive potential there is a sudden and large increase in the current flowing from the battery B_2 through the telephones and, if it is charged negatively, the battery current falls in value, in either case a click is produced in the telephones. The current actuating the telephone receiver, it will be seen, is not the rectified current between the grid and the filament, but is derived from the battery B_2, and the variation of this current being much larger, the signals in the telephones are consequently much stronger.

The valve is adjusted by varying the filament current and by varying the voltage of the battery B_2. If the telephones are connected directly in the circuit, they should be so connected that the steady current passing through them is not flowing in such a direction as to demagnetise them. It is for this reason preferable to connect them to the circuit through the windings of a transformer. If low-resistance telephones are used, the transformer should be of the step-down variety, if high-resistance telephones are used, the windings of the transformer will have an equal number of turns.

Thermo-Electric Detectors

If the junction between two dissimilar metals forming part of a closed circuit be heated a current will be produced in the circuit. For instance, suppose we take a piece of the metal bismuth and a piece of antimony, place them in contact and connect their free ends to a suitable galvanometer we shall find that if the junction be heated to a higher temperature than the rest of the circuit that a current will flow in the direction bismuth to antimony, the current being proportional to the

excess of temperature. In any good text-book on electricity will be found a table showing the thermo-electric series of metals with their thermo-electric power or electromotive force per degree centigrade when used in conjunction with lead. For instance, suppose we formed a couple of tellurium and lead and heated it to 1° centigrade above the rest of the circuit, the E.M.F. produced would be about 500 micro-volts.

It has been found that some of the metallic sulphides,

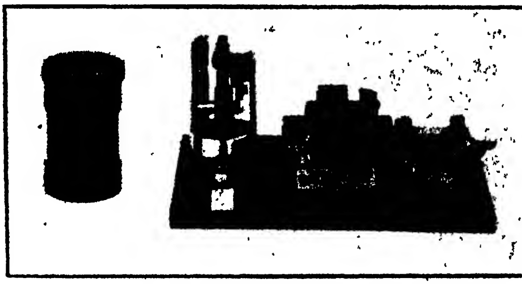

FIG. 72.

for instance, galena, exhibit very marked thermo-electric power, and therefore, galena usually forms one of the elements in a thermo-couple when used as a detector for wireless telegraphy.

Two very efficient combinations for the purpose are galena graphite and galena tellurium, both being extremely sensitive. The construction of such a detector can be seen from Fig. 72. The galena crystal is soldered in the holder by woods metal (this metal will melt in boiling water) and the graphite may be any fairly hard pencil, the refills sold for use with propelling pencils being very convenient.

A small screw is provided for adjusting the pressure.

Being a current actuated-device, the thermo-junction is connected in series with the condenser, and on the passing of oscillations it is heated and a small potential difference thereby is created at its terminals and charges the condenser which discharges through the telephone receiver.

With a good galena crystal the detector requires very little attention, but the passage of strong atmospherics sometimes throw it out of order, due no doubt to its behaving like a coherer and the surfaces of the electrodes become slightly welded together. If the graphite and galena are just pulled apart and then allowed to come together again it will be found that its sensitiveness is fully restored.

Magnetic Detector

The Marconi magnetic detector consists of an endless band built up of 70 strands of number 40 silk-covered iron wire. The band passes over two grooved pulleys which are kept in rotation by a clockwork motor and at a certain point in its journey passes through a small glass tube wound for a length of about two centimetres with a layer of number 36 silk-covered copper wire the ends of this wire which form the primary winding being brought out to terminals. Over this winding is a small bobin wound with wire of the same gauge to a resistance of about 140 ohms, this forms the secondary winding and the ends are taken to terminals to which the telephone receivers are also connected. Above the coils are arranged two permanent horseshoe magnets, with like poles together as shown in diagram The detector depends for its action on the fact that electrical oscillations have the ability to annul the

magnetic hysteresis of iron. Reference to Fig. 73 will perhaps help to make this plain. Suppose a certain piece of soft iron, say the core of an alternating-current transformer, to be subjected to a magnetising force H which rises to a maximum, descends to zero, then attains a maximum in the reverse direction and again descends to zero, it will be found that if the magnetising force H is plotted against the density of the lines of force B the curve will assume the shape shown in Fig.

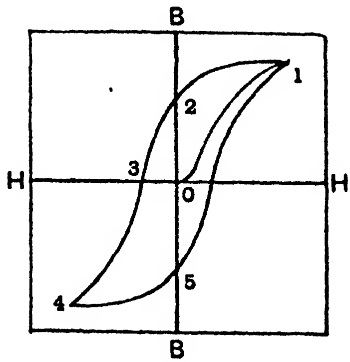

FIG. 73.

73. Starting from zero, if the magnetising force is gradually increased to the maximum and the value of the flux density for each increment of the magnetising force noted, we get the curve to 1. If now the force is decreased to zero the curve will not return on itself, but will follow the direction 1, 2, and if the iron be now subjected to a magnetising force in the reverse direction the curve will take the position 2, 3, 4, 5. It will thus be seen that the magnetic effect produced on the iron owing to its hysteresis lags behind the magnetising force operating to produce it, and that

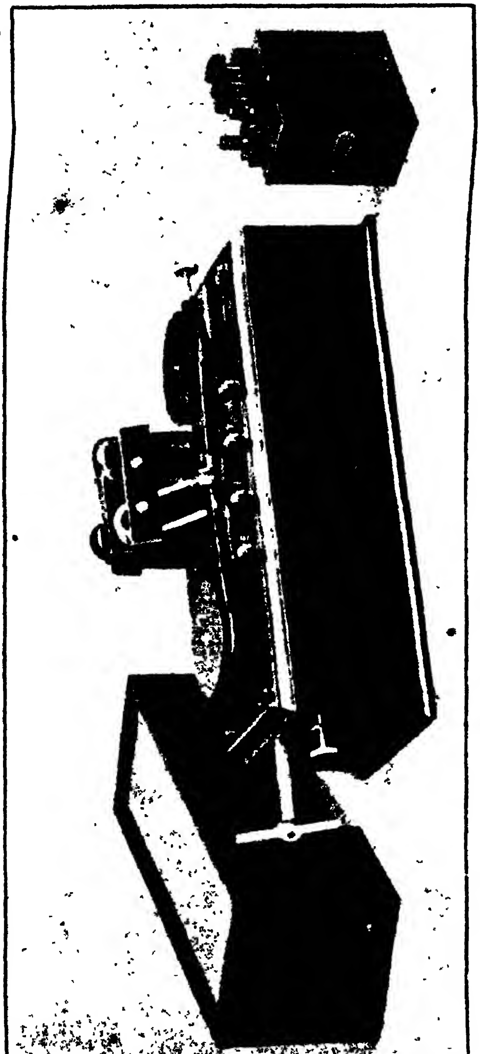

Fig. 74.

Marconi magnetic detector (cover removed) and telephone condenser.

after it has been magnetised it will retain its magnetism for some time after the withdrawal of the magnetising force. It is this lagging that the electrical oscillations passing through the primary annul. Consider now the magnetic detector itself. We have here a soft iron band passing before the poles of two permanent magnets; as each portion of the band passes the poles it becomes magnetised and by the action of the clockwork motor this magnetised portion is carried forward. If now electrical oscillations pass through the primary

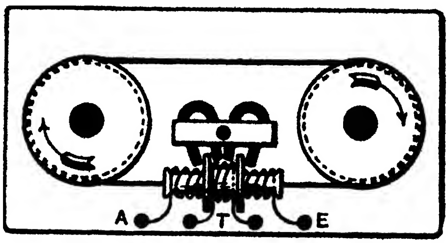

Fig. 75.
Magnetic detector.

windings the hysteresis of the band is annulled and the magnetised portion which has moved out of the field of the magnet has its magnetism destroyed and a redistribution of the lines of force through the secondary winding takes place, which sets up a current in it and the telephone receivers which are connected to it and a sound is thus produced.

Fig. 74 shows the instrument as manufactured by the Marconi Company; it will be seen that there are two sets of coils and magnets, the clockwork and moving iron band being common to both. In the event of one side breaking down all that is necessary

is to change over to the other side. On the left hand of the instrument is the winding key and the key to start or stop the clockwork, the adjusting screw at the top of the instrument to the right is to regulate the tension of the moving iron band.

Fig. 75 is a diagram of the detector and shows the magnets in the most sensitive position—*i.e.*, with like poles together. In this position, although very sensitive, a breathing noise is sometimes produced in the telephone which is very disturbing when reading weak signals. This can be overcome by placing the magnets, as in Fig. 76, with unlike poles together, the pole of

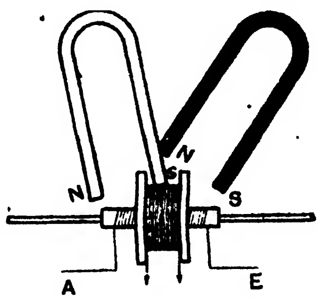

FIG. 76.

one being some little distance up the limb of the other, or by moving the magnets away from the band, the best position being found by experiment. The magnets used on this detector have one face brightly polished and the other blackened. When both bright faces or both black faces are to the front like poles will be together, when one bright and one dull face are to the front unlike poles will be together. In practical use this detector has proved itself to possess the great

merit of reliability, and needs practically no attention beyond occasional winding of the clockwork.

Telephone Receivers

The telephone receivers used for the reception of wireless messages are not essentially different from those in ordinary commercial use; they, however, differ somewhat in the minor details of construction.

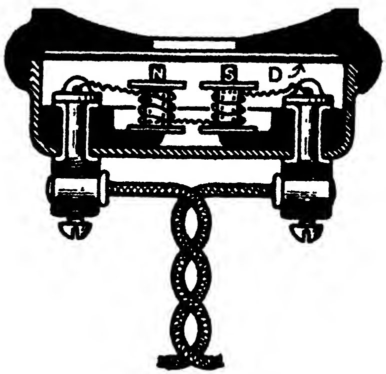

Fig. 77.
Telephone receiver.

As is well known, the telephone receiver consists essentially of a permanent magnet of the horseshoe type, having at its poles soft iron extensions on which are wound a quantity of insulated copper wire, the two coils being joined in series and the free ends brought out to terminals; immediately in front of the pole-pieces, and close to them, is a flexible soft iron disc or diaphragm clamped firmly about its periphery. Fig. 77 shows clearly the construction. Two such receivers are joined in series and attached to a leather-covered metal band, which passes over the head of the

operator so that the telephones fit over the ears. As the telephones are usually in circuit with a high-resistance detector, and the effect depends on the ampère turns, it is customary to wind them to a much higher resistance than the ordinary commercial type, the resistance being from 500 to 5,000 ohms according to the nature of the circuit on which they are to be used. As it would be impossible to get the requisite number of turns into the small space of the bobbin, if ordinary silk or cotton insulated wire were used, the bobbins are wound with an enamel insulated wire which occupies much less space.

The telephone receiver is acknowledged to be one of the most sensitive appliances for detecting the presence of an electric current ever invented, its sensitiveness can be judged from the fact that an intermittent current of only a few microamps produces an easily audible sound in it. The loudness of the sound, however, depends not only on the value of the current but on its frequency; it has been ascertained that the telephone receiver has a maximum sensitiveness to frequencies lying between 600 and 1,000 per second. This is no doubt due to the fact that the natural frequency of the diaphragm is something of this order, and also perhaps to the fact that the human ear is affected more strongly by these frequencies.

CHAPTER V

MISCELLANEOUS RECEIVING APPARATUS

The Testing Buzzer—Shunted Buzzer—Telephone Relay—The Variometer—Elimination of Atmospherics

THIS piece of apparatus, the purpose of which is to test the receiver, consists of an electro-magnetic vibrator and in construction is exactly similar to a trembler bell, but without the gong. Two extra terminals are provided and are connected one to each side of the contact-breaker. If we connect to one of these terminals a yard or so of wire supported in a vertical position and connect the other terminal to earth we are in possession of a miniature plain aerial transmitter, capable of generating and radiating electrical oscillations of such a strength as to produce signals of about the same intensity as those emanating from a more powerful but distant station. The action is as follows: when the switch is closed current flows through the coils of the magnet and a magnetic field is built up round them, the magnets being now excited the armature is attracted and the circuit being thus broken the lines of force collapse and cut across the winding of the coils. This cutting of the coils by the lines of force sets up a difference of potential at the point at which the circuit is broken—viz., the contact-breaker, to which, as we have already seen, is attached a miniature aerial and an earth connection. The potential difference produced at the break owing to the great self-inductance of the coils is sufficiently high

to jump the small gap formed and the aerial is therefore charged to this potential, and on the passing of the spark, electrical oscillations are set up and radiated from it. Fig. 78 shows the buzzer. The battery and key are connected to terminals marked B, K, and the small aerial and earth wire to terminals A and E.

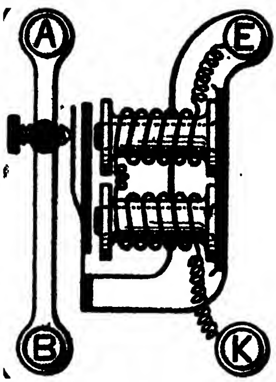

FIG. 78.
Testing buzzer.

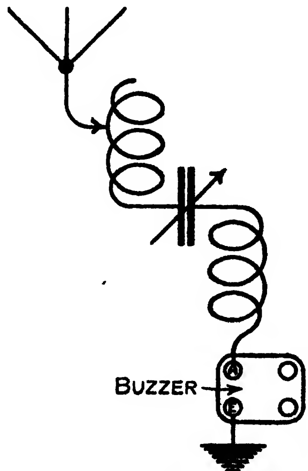

FIG. 79.

It should be noted that the production of a sound in the telephone receiver does not necessarily indicate that the whole of the receiver is in order, and that signals could be received from a distant station; all that the test proves is that the detector and telephones are in order. The most satisfactory evidence that the receiver is in working order is to tune in signals from a distant station, but these are not always available when required; the operator should therefore proceed as follows: First, supposing the tuner to be of the

three-circuit type, set the condenser of the intermediate circuit at some convenient value, then detach the earth lead from the tuner, and connect in circuit the terminals of the buzzer marked A, E, as in Fig. 79, set the buzzer going and adjust the primary circuit till resonance is attained which will be indicated by maximum sound being produced in the telephones; the coupling between the circuits should be very loose. If this test is made when the station is known to be in working order and the adjustment of the condenser and variable inductance in the primary circuit noted, it can be repeated at any subsequent time; and if resonance is attained with the same adjustments, it is proof that the receiver is still in working order. What we are in effect doing is to produce in the aerial circuit by local means comparatively feeble oscillations, and then by means of the calibrated intermediate circuit ascertaining that the capacity and inductance of the primary circuit have not altered.

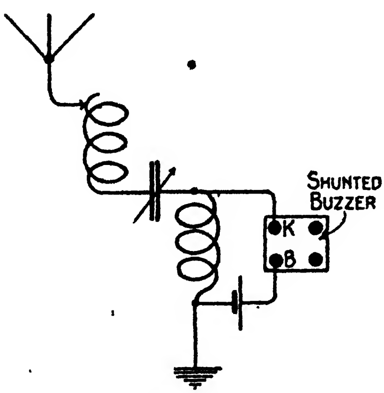

FIG. 80.
Showing method of connecting shunted buzzer to circuit.

THE SHUNTED BUZZER

In construction, the shunted buzzer is the same as the sparking buzzer, but has connected across its coils a high non-inductive resistance. The purpose of this resistance is to eliminate the sparking at the contact-breaker, it does this by providing an alternative path

through which the self-induced current can flow. The purpose of the shunted buzzer is to provide a means for exciting weak electrical oscillations in a circuit, for testing or measuring purposes.

The method of connecting the shunted buzzer to the circuit is shown in Fig. 80. It will be seen that the current from the battery of cells flows through the coupling coil of the circuit, a magnetic field will therefore be set up around it. On the opening of the contact-breaker, these lines of magnetic force will collapse and in so doing will produce a difference of potential, which charges the condenser in the circuit, which afterwards discharges through the coil, producing oscillations. Oscillations produced by the shunted buzzer, are less damped than those produced by a sparking buzzer, as there is no spark-gap in the circuit.

The Telephone Relay

This instrument, the invention of Mr. S. G. Brown, has for its object the stepping up or magnification of feeble telephone currents, thus rendering them more audible.

It consists of a novel kind of microphone formed of two pieces of hard osmium iridium alloy, separated to an infinitesimal degree by the adjoining screw W (Fig. 81) and by the action of the local current which flows through it and the winding K (Fig. 81). The local current assists in forming the microphone by rendering the small space between the contacts conductive and after the relay has been actuated by the passage of current through the winding H it restores it to its original adjustment by means of the regulating winding K.

Fig. 81 shows clearly the construction of the relay. Fig. 82 gives an enlarged view of the microphone contacts and shows the position the reed should occupy with regard to the magnet H. Fig. 83 shows

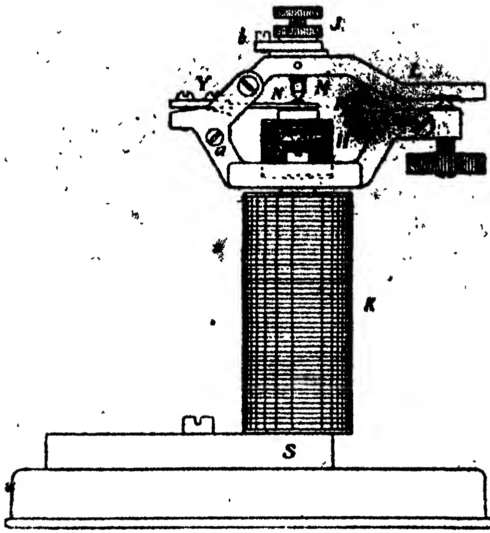

FIG. 81.

the connections of the relay: *the terminals A should* be connected to the receiving circuit in place of the ordinary telephones. The local circuit consists of the microphonic contacts, the regulating winding K, a dry cell, milliampère meter and telephone receiver all in series. The working of the relay appears to be as follows: supposing the telephone circuit to be magnified circulates through the winding H in such a direction as to increase its magnetism the reed P will be pulled towards the magnet, and, the resistance of the

microphone being thus altered, a sound will be heard in the telephones, and as the local current is taken through the winding K, in such a direction as to assist the magnetism of the permanent magnet, any opening of the microphonic contact and thereby increase of its resistance [illegible] the current to fall, a[illegible] magnet thereby being weakened the reed P resumes its normal position. Also it will be seen that should the current in the winding H be in such a direction as to oppose the permanent magnet, the microphone will lower its resistance owing to the removal of part of the force which is acting against the stiffness of the reed P and tending to hold the contacts apart and then, owing to the decrease in resistance of the microphone and consequent rise in local current strength, the power of the magnet will be increased and the reed pulled back to the normal position. The inventor is of opinion that the resistance of the local circuit should not much exceed 6 ohms and that the voltage of the local battery

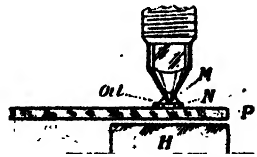

Fig. 82.

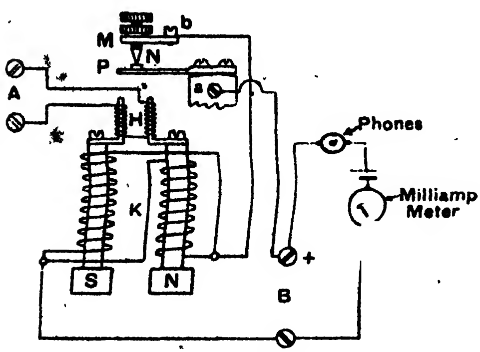

Fig. 83.

should be ·5 of a volt. This voltage he obtained by putting in opposition to each other a dry cell whose voltage was 1·5 and a 2-volt accumulator cell.

The writer, however, has obtained excellent results using phones whose resistance was about 60 ohms and a single dry cell. It was found that signals which were quite inaudible when the ordinary means of reception were in use could by the interposition of the relay be distinctly heard, and when the signals were of average strength the use of the relay made them so loud as to be easily read at distances varying from 10 ft. upwards from the phones.

A small drop of thin oil placed on the lower contact increases the reliability of the arrangement. It is also necessary to support the relay on a felt or rubber pad to protect it from outside vibration. For the same reason all connecting wires should be flexible, as if they are solid and stiff the slightest touch causes them to vibrate and the vibration being transmitted to the relay is heard in the phone magnified many times. Using a voltage of 1·5 and phones whose resistance was about 60 the milliampère meter read from 10 to 15 milliampères when the relay was in the most sensitive adjustment.

A later pattern of relay uses a carbon granule microphone in place of the single contact device. This latter pattern keeps its adjustment better, but is not so sensitive.

Amplification of Signals by the Three-Electrode Valve

The three-electrode valve can, with suitably-arranged circuits, be used as an amplifier. The circuits are as

shown in Fig. 84, and it will be seen that the telephones have been replaced by an oscillating circuit, consisting of a variable condenser and an inductance, the latter being divided into two parts. This circuit, which is termed the plate circuit, must be adjusted to the same frequency as the incoming oscillations, and

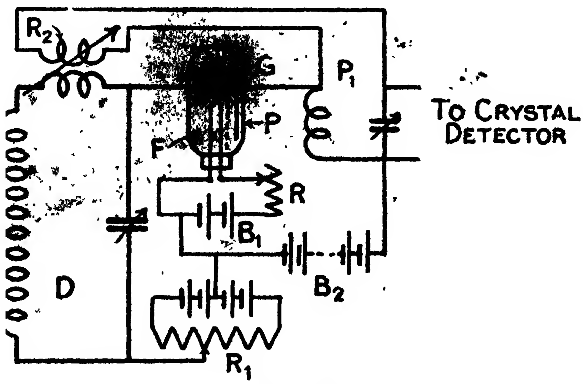

Fig. 84.

D. Detector Circuit.
F. Filament.
G. Grid.
P. Plate.
R. Resistance to vary Filament current.
R_1. Potentiometer.
R_2. Reaction Coil.

one part of the inductance so placed that it can act inductively on the detector circuit of the tuner. The grid potential is adjusted by means of the potentiometer, not to the point at which the received oscillatory currents are rectified, but to a point on the steep part of the curve. When this adjustment is made oscillations produced in the detector circuit will, by varying the grid potential, produce in the plate circuit oscillations of the same frequency but of larger amplitude. This circuit, by reacting on the detector circuit

of the tuner, will still further increase the potential variations of the grid, and by so doing largely increase the amplitude of the oscillations in the plate circuit. The amplified currents are rectified by a carborundum crystal connected across the condenser in the plate circuit in the usual way. The best degree of coupling between the detector circuit and the reaction coil which forms part of the plate circuit is found by experiment. The closer the coupling is made, the greater will the amplification be, but if made too close, the valve once started will continue to oscillate, thus acting as a generator of continuous and undamped oscillations, which would make the reception of signals impossible. From this it will be seen that the three-terminal valve can be used as a transmitter, providing the plate circuit is an open or radiating circuit, or is coupled to such a circuit. For the purpose of wireless telephony, where continuous and undamped oscillations are a necessity, the valve transmitter has proved very useful.

The Variometer

The variometer is a form of variable inductance in which, however, the usual sliding contact is absent. It consists of two ebonite frames on which are wound the coils of wire. One end of each coil is connected by a flexible wire and the remaining ends are brought out to terminals; the inner coil is pivoted and is free to move about its vertical axis It will be seen from Fig. 85 that when the inner coil is in the position shown, the wire on the frames forms a continuous coil of two layers, the winding being all in one direction; this is the position of maximum inductance.

If, however, the inner coil be turned through 180° it will be observed that the wire doubles back on itself and forms a bifilar or non-inductive winding: the variometer is usually provided with a pointer moving over a scale divided into 180°. The advantages of this form of inductance are that sliding

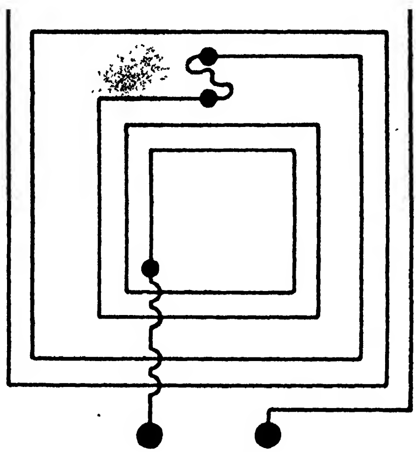

FIG. 85.

Variometer.

or rubbing contacts which often become dirty and thereby introduce a high resistance into the circuit are avoided, the inductance also is continuously variable practically from zero to a value determined by the dimensions of the coils, and occupies less space than the older types.

Elimination of Atmospheric Disturbances

Many devices have from time to time been suggested, for the elimination, or mitigation, of atmospheric

disturbances. The underlying principle of the majority being, to so arrange two detectors, that only one should be operative to signals of ordinary strength, but both actuated by atmospherics. The detectors are so connected to the telephones as to pass equal and opposite currents through it, thus producing no effect on the diaphragm. A good example, and one much used by the Marconi Company, is the balanced crystal receiver. It consists of two carborundum crystals connected in parallel with each other and in series with the telephones (Fig. 86). The crystals are so arranged as to rectify in opposite directions; the crystal marked A being adjusted to sensitiveness by means of a potentiometer and battery of cells, the crystal marked B being made insensitive by shifting back the slider of the potentiometer, to which it is connected. The sensitive crystal A will rectify oscillations of normal strength and, as the insensitive crystal B is practically inoperative, the telephones will be actuated by the rectified currents. If atmospherics excite powerful oscillations in the receiver circuits, both crystals will be actuated, consequently, as both half-cycles of the oscillatory current pass through the telephone windings, no sound will be produced. The method of connecting the crystals to the potentiometers and to the circuits of the tuner is shown in Fig. 126, Chapter VI.

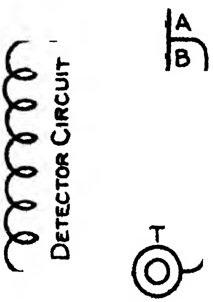

FIG. 86.
Marconi balanced crystal receiver.

CHAPTER VI

THE MARCONI SYSTEM

The Transmitter 1½ kw. Set—The Emergency Transmitter—Charging Switchboards—Multiple Tuner—Magnetic Detector—Telephone Condenser—Fleming Valve Tuner—Crystal Receivers

As an example of the Marconi system we have chosen the 1½ kw. installation, as it is perhaps in more general use than any other set manufactured by that company. The general principles of the transmitter and the receiver have already been dealt with and this chapter will therefore be mainly descriptive of the apparatus. A rotary converter is used to convert the direct current from the ship's dynamo into an alternating current. The machine has four poles and runs at a speed of 1,500 revolutions per minute, the frequency of the alternating current will therefore be 50. Across the brushes on both the alternating and direct-current side, a special form of lamp resistance is connected. These are known as the guard lamps and provide a path of low self-inductance to shunt out any high-frequency currents which might be set up in the circuit by induction from the oscillatory circuits of the transmitter and cause damage to the machine.* The

* High-frequency currents will, if two paths are open to them, divide in inverse proportion to the inductances of the paths. The inductance of the guard lamps is very small compared with that of the coils of the converter, therefore practically the whole of any high-frequency current set up in the circuit would pass through it.

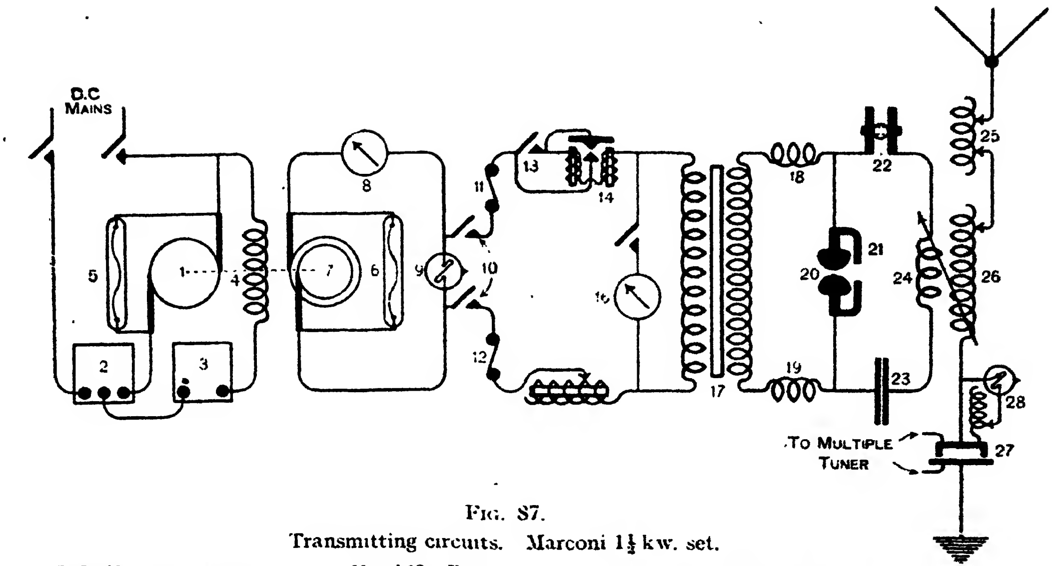

FIG. 87.

Transmitting circuits. Marconi 1½ kw. set.

1. D.C. side rotary converter.
2. Motor starting switch.
3. Field regulating resistance.
4. Field winding.
5 and 6. Guard lamps.
7. Slip rings rotary converter.
8. Ampère meter.
9. Pilot lamp.
10. Double-pole switch.
11 and 12. Fuses.
13. Morse key.
14. Magnetic key.
15. Reactance regulator.
16. Voltmeter.
17. A.C. transformer.
18 and 19. Air core chokes.
20. Spark-gap.
21. Safety spark-gap.
22. Sliding inductance.
23. Condenser.
24. Primary oscillation transformer.
25. Aerial tuning inductance.
26. Secondary of oscillation transformer.
27. Earth arrester.
28. Tuning lamp and choke.

transmitter of this set consists of five circuits—namely, the direct-current circuit, the low-tension alternating-current circuit, the high-tension alternating-current circuit, and the primary and secondary high-frequency circuits. The direct-current circuit consists of the motor starting switch, the field regulating resistance and the direct-current side of the rotary converter connected together and to the direct-current supply of the ship as shown in Fig. 87. The internal connections of the starter are shown in Fig. 88, and it will be

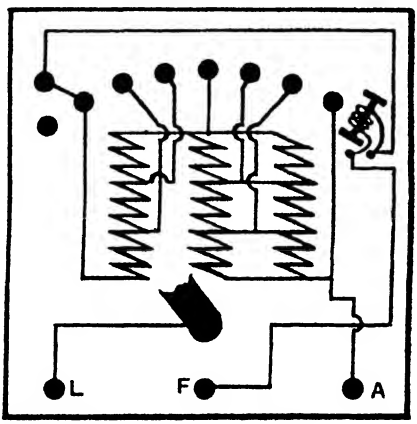

Fig. 88.
Motor starting switch.

seen that it differs somewhat from the ordinary pattern. As the arm of the switch is moved over the contacts, the resistance which at the start was in series with the armature coils is transferred to the field circuit, as this weakens the field it enables the motor to start quickly. The small electro-magnet on the face of the starter is termed a no-volt release and serves

while the machine is running to hold over the arm of the switch and should the power-supply fail or the field circuit be broken, the arm will be released and move over to the off position, and cut the motor out of circuit. The low-tension alternating-current circuit consists of the primary of the transformer, Morse key, magnetic key, and impedance coil, which together with the ampère meter and fuses are connected in series and to the slip rings of the alternating-current side of the rotary converter as in Fig. 87.

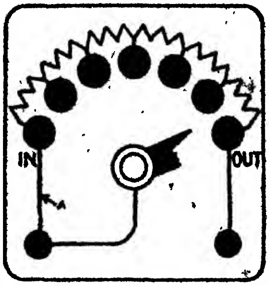

FIG. 89.

Field regulating resistance.

Connection marked A prevents interruption of field circuit, should arm of switch fail to make contact with the studs.

Fig. 90 shows the internal connections of the alternating-current transformer. It will be seen that it really consists of two open core transformers placed side by side in the same case, and that the primaries and the secondaries can be connected in series or in parallel as necessity requires.

The case is filled with oil to improve insulation. The action of the magnetic key has already been described in an earlier chapter, Fig. 93 shows the internal connecting of the key as used on the $1\frac{1}{2}$ kw. set, and the method of connecting it to the Morse key and to the circuit.

The coils of the magnetic key, it will be seen, are connected in parallel, the object being to reduce the inductance of the coils and so prevent sluggishness of action.

The Morse key is of the heavy contact type, but connection between the lower contact and its terminal

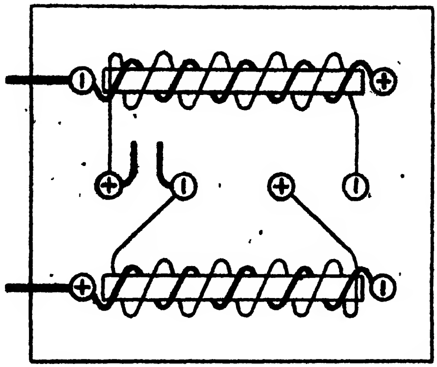

FIG. 90.
Internal connections. A.C. transformer.

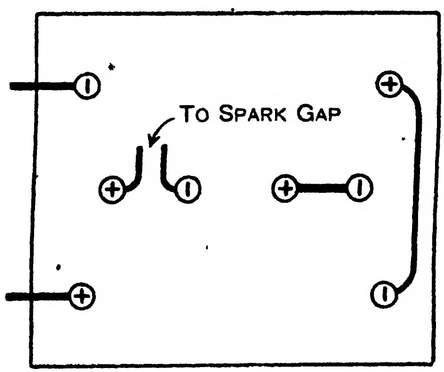

FIG. 91.
A.C. transformer. Primaries and secondaries connected in series.

is made through a side lever, which provides a means of breaking the alternating-current circuit ready to the

hand of the operator in case of emergency. The lever of the Morse key also carries a small ebonite arm, which closes a pair of contacts so arranged and connected as to short-circuit the telephone receiver before the main contacts of the key close.

The volt and ampère meters, the fuses, the double-pole quick-break switch, and the pilot lamp are mounted together on a slate panel (Fig. 94). The

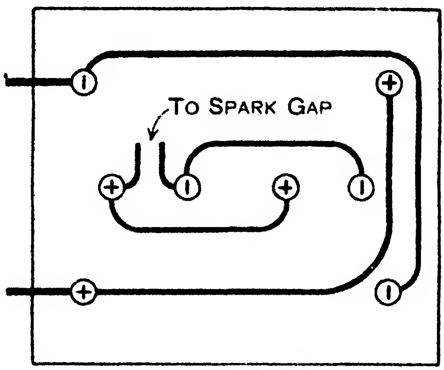

FIG. 92.

A.C. transformer. Primaries and secondaries connected in parallel.

high-tension alternating-current circuit consists of the secondary of the transformer connected through two air core chokes to the spark-gap and so to the condenser. The purpose of the chokes is to prevent the high-frequency currents in the closed oscillatory circuit from flowing back into the secondary of the transformer.

Formerly, the leads from the secondary terminals of the transformer were taken directly to the condenser, but present-day practice is to make connection to the

spark-gap terminals, as the oscillatory difference of potential there is much less than at the condenser terminals, consequently there is less liability of damage to the transformer.

The primary or closed oscillatory circuit consists of the condenser, spark-gap, primary of oscillation transformer, and a variable inductance all connected in series.

The condenser, the plates of which are zinc, and the dielectric of which is glass, is so constructed that by changing the positions of the connecting strips between its terminals its capacity can be reduced to one-fourth of its maximum capacity (max. capacity = ·065 mf.). This provides a means of changing from the 600 to the 300 metre wave. Figs. 95, 96, 97, show the internal connections of the condenser and the positions of the connecting strips for the two wave-lengths. The numbers on the terminals indicate the number of plates connected to each terminal. When working on a 600-metre wave, the secondaries

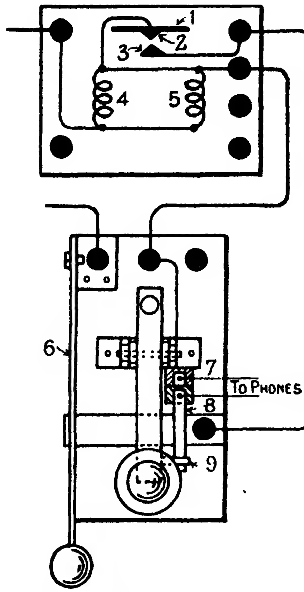

FIG. 93.

Showing method of connecting magnetic and Morse keys.

1. Armature of key.
2 and 3. Contacts of key.
4 and 5. Coils of key.
6. Safety Switch.
7 and 8. Short-circuiting contacts for telephones.
9. Ebonite arm. The internal connections to terminals not used, are omitted, for clearness.

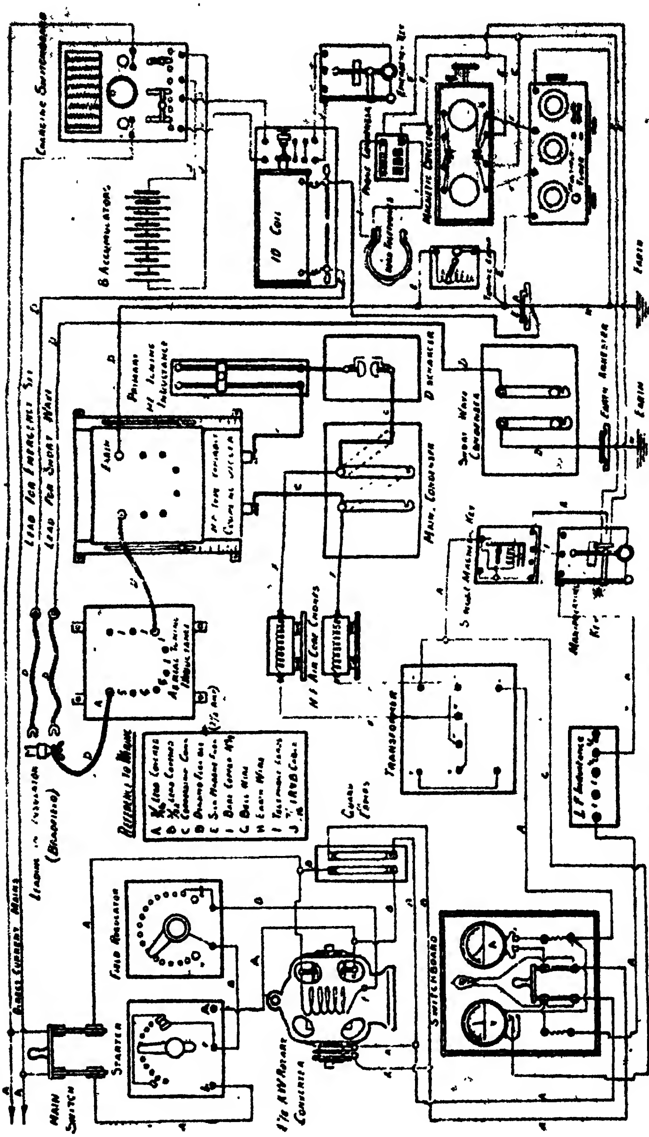

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Fig. 94.

Wiring diagram. Marconi 1½ kw. set.

of the transformer should be connected in parallel, and when working on the 300-metre wave, they should

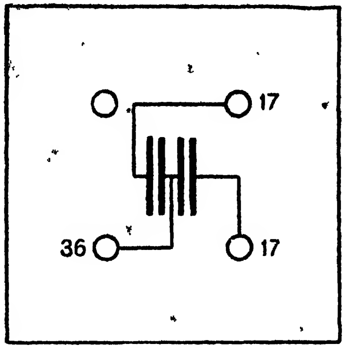

FIG. 95.
Internal connections of condenser.

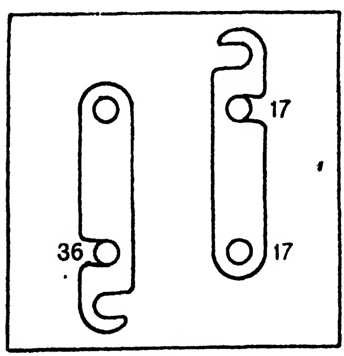

FIG. 96.
Condenser. Position of connecting strips for 600-metre wave.

be in series and the spark-gap doubled in length. The purpose of making these changes, is to keep the spark frequency and the energy stored in the condenser

before discharge constant. The energy stored in a condenser is proportional to the product of its capacity, and the square of the voltage to which it is charged, therefore, as the capacity of the condenser has been reduced to one-fourth in order to get the 300-metre wave, we must charge it to double the voltage, if we wish to keep the energy constant.

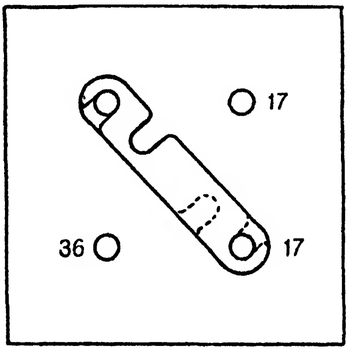

FIG. 97.

Condenser. Position of connecting strips for 300-metre wave.

The variable inductance consists of two brass rods connected together by means of a sliding metallic bridge, the position of which determines the amount of inductance included in the circuit. The purpose of this inductance is to secure the exact adjustment of the circuit to a given wave-length after the main adjustment has been made on the condenser, it is also used to compensate for any loss of capacity due to the breakage of one or more of the condenser plates, sufficient inductance being added to bring the wave-length back to its original value.

The spark-gap which is enclosed in a muffling chamber is shown in Fig. 98. It consists of two steel hemispheres, the length of the gap can be adjusted by turning either of them.

The usual lengths of gap used are 3 to 4 millimetres when the condenser is connected in parallel, and 6 to

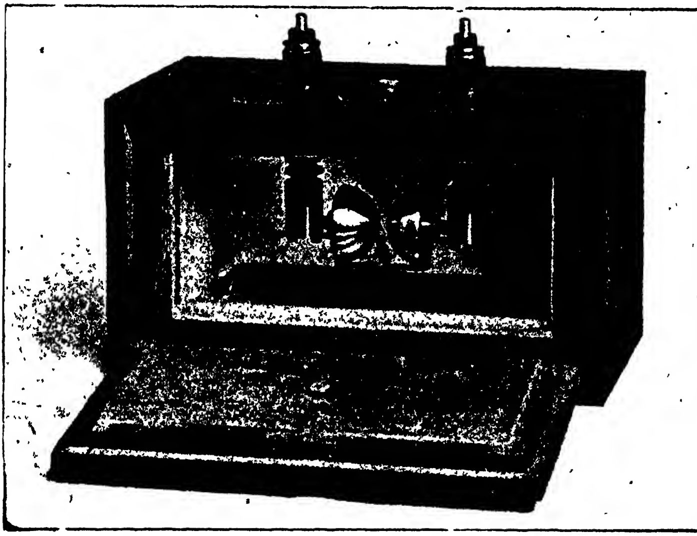

Fig. 98.
Spark-gap.

8 millimetres when the condenser is connected in series. In parallel with the main spark-gap is another formed of two pointed brass rods; the length of this gap, which is kept constant, is determined by the safe voltage to which the condenser can be charged, and its purpose is to protect the condenser from excessive voltages which might puncture the dielectric.

Connection between the various pieces of apparatus in this circuit is made by means of flat copper strips and not ordinary round sectioned conductors. These copper strips have large surface and therefore their resistance to high-frequency currents is low, also they are placed parallel and near together (about $\frac{1}{8}$ in. apart), and the space between them filled with strips of hard rubber. The purpose of placing the strips parallel and close together is to neutralise their inductance, and the purpose of the solid insulator is to prevent sparking between them.

The inductance of the circuit therefore consists almost entirely of the primary of the oscillation transformer and practically the whole of the inductance can therefore be utilised for coupling purposes.

The secondary or open oscillatory circuit is made up of variable tuning inductance, secondary of oscillation transformer, the inductance of which is also variable, and a special form of spark-gap called by the Marconi Company an earth arrester terminal all connected together in series and to aerial and earth. The tuning of the circuit is effected by varying the inductance and the coupling can be varied by sliding the secondary over the primary. The earth arrester terminal (Fig. 99) consists of two brass plates separated except for a small space round the edge by a mica washer. The receiving apparatus is connected across the spark-gap so formed, and its purpose is to obviate the necessity for a change-over switch and so permit the receiving operator to interrupt the sending operator during the course of transmission if necessity requires. Its action is as follows: during the time the Morse key is closed the receiver is shorted out by the sparks which pass

between the plates, but the moment the key is opened the path of incoming oscillations will be through the primary circuit of the tuner as the received oscillations are not of sufficient intensity to jump the gap. Shunted across about a yard of the earth lead is a small incandescent lamp in series with a variable choking coil; the purpose of the lamp is to indicate when the primary

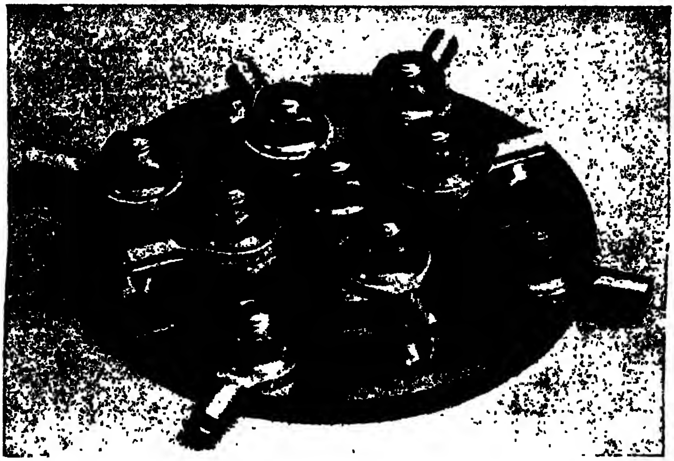

FIG. 99.
Earth arrester terminal.

and secondary circuit of the transmitter are in tune. The brilliancy of the lamp will, of course, be a maximum when resonance is obtained. The function of the variable choke is to regulate the current through the lamp and thus to protect it from excessive currents which might burn out its filament. If a high-frequency current has two paths open to it, it splits up in inverse proportion to the inductance of the paths and therefore

if inductance is inserted in the branch in which is the tuning lamp, the current through it will be diminished.

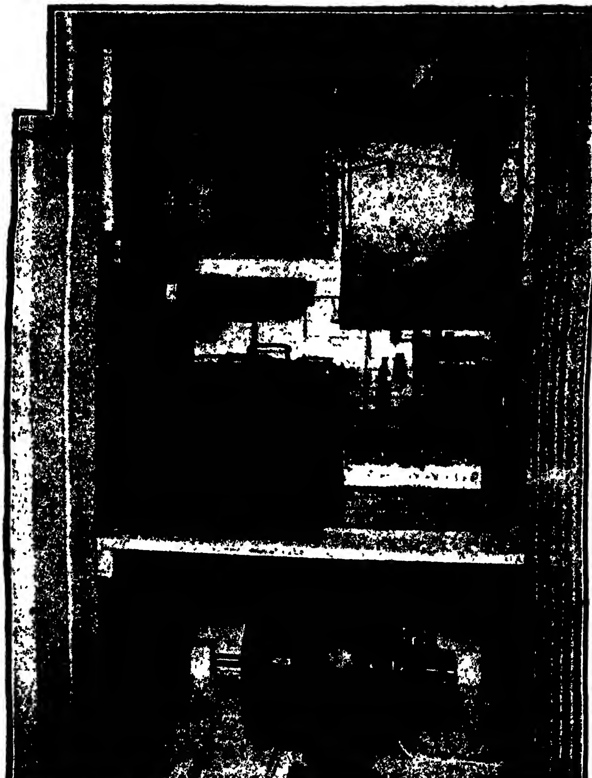

FIG. 100.
Transmitting apparatus mounted in silence cabinet.

SHORT WAVE CONDENSER

In the case of an installation, the natural wave-length of whose aerial, plus the necessary coupling coil

is greater than 300 metres, it is necessary to insert in series with the aerial, a condenser in order to reduce the wave-length to this value.

If this condenser were inserted in the earth lead in the usual way, it would render inoperative the high self-inductive shunt in the tuner as there would no longer be a metallic path to earth owing to the dielectric of the condenser. It is, therefore, the practice of the Marconi Company to connect up the short wave condenser as shown in Fig. 101.

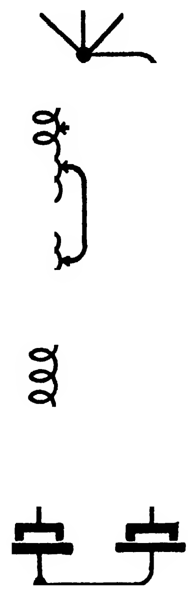

FIG. 101.
Showing method of connecting short wave condenser.

The condenser, the construction of which is the same as that used in the closed oscillatory circuit, has the capacity of each of its banks adjusted so that if either of them were placed in series with the aerial a 300-metre wave would be produced; the banks are then connected in parallel in the usual way, by means of the terminals and connecting strips. The condenser so built is then connected between the leading-in insulator and the top plate of a second earth arrester, the bottom plate of which is earthed. After connecting the short wave condenser, the aerial tuning inductance should be varied until the tuning lamp indicates resonance.

The purpose of the second earth arrester is to automatically disconnect the short-wave condenser

as soon as transmission ceases. If this were not done, the closed circuit formed by the aerial tuning inductance, the secondary winding of the oscillation transformer, and the short wave condenser, would prevent *the reception of signals on* a 300-metre wave-length as the received oscillatory currents would be chiefly expended in this circuit.

Marconi $1\frac{1}{2}$ Kilowatt Set, with Rotary Discharger

On the later Marconi ship installations the fixed gap is replaced by one of the rotary type. The gap may have the same number of rotating studs as there are poles on the alternating machine, in which case it is known as a synchronous gap, but more usually it has 24 studs, on account of the higher spark frequency thus obtained. Connection to the rotary gap is made by the prolongation of the flat copper connecting leads through the bench; this, by adding to the inductance of the closed circuit, necessitates a reduction in the capacity of the condenser in order not to increase the wave-length. The capacity is about two-thirds of that used with the fixed discharger, and the connecting strips on the condenser are mechanically coupled, so that one movement suffices to change the wave-length.

With a 24-stud discharger, in addition to the reduction of the condenser capacity, it is also necessary to reduce the transformation ratio of the alternating-current transformer.

Best results are obtained when the low-frequency circuit is adjusted to the spark frequency, and a high ratio of transformation, such as is used with the fixed gap, would make this impossible. The transformer,

which is of the closed core type, is contained in a galvanised iron tank which is filled with oil. Only the secondaries are variable, the change from series to parallel being made by means of an arrangement of outside terminals and connecting strips similar to that used on the condenser. Fig. 102 shows the rotary gap. The fixed electrodes are of copper, and are so constructed that by turning the milled head at the top they can be fed forward to compensate for wear. On some installations the fixed electrodes make an angle of 90° with each other, on later installations they are set at an angle of 45°, as the wear on the moving studs is then much more even. With the electrodes set at 90° it is necessary to occasionally shift the carrier to equalise the wear on the moving studs. If the carrier is moved through 45°, the studs which formerly came opposite the fixed electrodes at maximum condenser voltage and consequently got most wear will now come opposite the fixed electrodes at zero voltage.

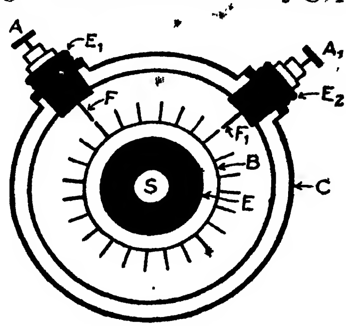

FIG. 102.

Rotary gap.

A_1, A. Milled heads.
E_1 E_2. Insulating sleeves.
F, F_1. Fixed electrodes.
E. Ebonite disc.
S. Shaft of machine.
B. Brass ring carrying studs.
C. Case.

The fixed electrodes of a synchronous gap should be set in such a position that the spark takes place at the moment the condenser reaches maximum voltage. This position may best be found by turning the carrier, and noting the brilliance of the tuning lamp, or the

reading of a hot wire ampère meter connected in the base of the aerial.

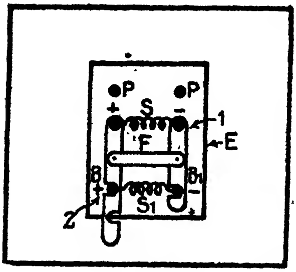

Fig. 103.
Tank transformer.

P.P. Priming terminals.
S, S_1. Secondaries.
B, B_1. Brass connecting strips.
1 and 2. Sockets for making connection to closed oscillatory circuit.

Before starting the machine, it is advisable to turn the disc by hand in order to ascertain that the moving studs can pass the fixed studs without collision.

Emergency Transmitter

In addition to the above-described transmitter it is the practice of the Marconi Company to provide an emergency set which is quite *independent of the ship's* machinery. The advantage of this provision will be apparent and has justfied the extra cost involved on many occasions. The set consists of a 10-in. induction coil, a battery of 8 accumulator cells and a special type of switchboard designed to facilitate the charging of the cells and to provide a ready means of changing the coil to or from the cells to the current-supply of the ship. Fig. 104 is a diagram of the coil connections; it will be seen that the condenser in the base of the coil, being across the contact-breaker and the Morse key in series, as well as serving its usual purpose of accelerating the rate at which the lines of force cut the secondary winding when the circuit is broken, also serves to eliminate the sparking at the key contacts. Copper pins form outside connections between the terminals B^1 and B^2, C^1 and C^2, and their removal will isolate the condenser for testing purposes. Fig. 109

is the charging switchboard. To charge the accumulators the double-pole switch is placed first in one

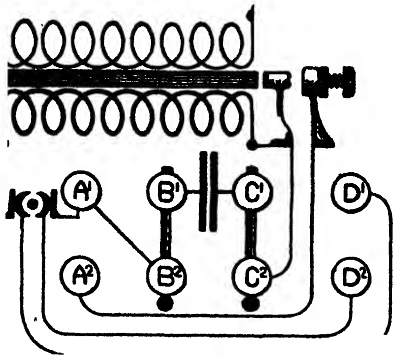

FIG. 104.
Connections. Marconi 10-inch induction coil. Morse key to A^1, A^2. Battery to D^1, D^2.

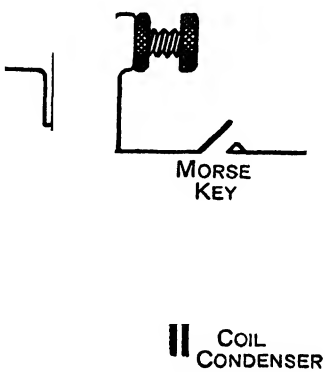

Fig. 105.
Showing position of coil condenser with respect to Morse key and contact-breaker.

position, then in the other: the correct position for charging being that in which the lamp resistances

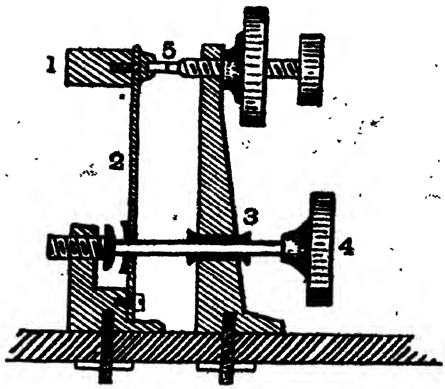

FIG. 106.

Showing construction of contact-breaker.

1. Hammer-head. 2. Spring. 3. Insulating collar. 4. Screw to adjust tension on spring. 5. Platinum contacts.

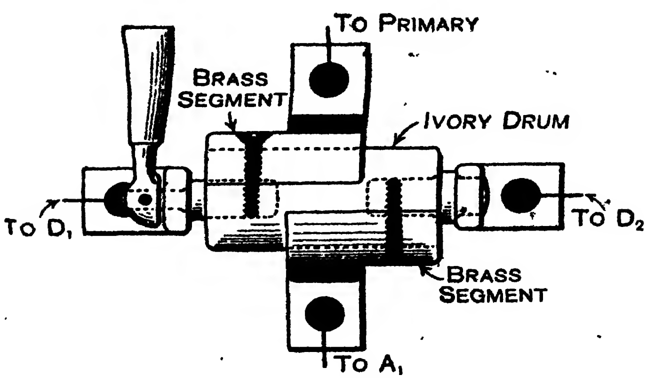

FIG. 107.

Commutator.

are dim. In this position the voltage of the cells is opposing that of the charging dynamo and the positive pole of the dynamo is therefore connected to the positive pole of the accumulators and the negative pole to the negative pole of the accumulators.

The voltage of the lamps used as resistances is chosen to suit the voltage of the ship's supply and the candle power to permit the correct charging current being

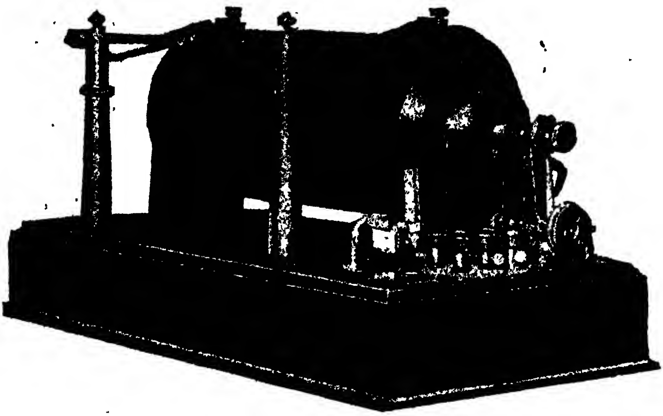

Fig. 108.
Marconi 10-inch induction coil.

supplied to the accumulators. The single-pole switch in one position enables the coil to be worked from the cells and in the other position from the ship's dynamo, the coil resistances at the top of the board being in series in order to cut down the current to the correct value. Fig. 110 will enable the composition of the circuits for different positions of the switch to be seen. It should be noted that when working off the dynamo

the lamp resistance must be removed and the double-pole switch may then be placed in either position.

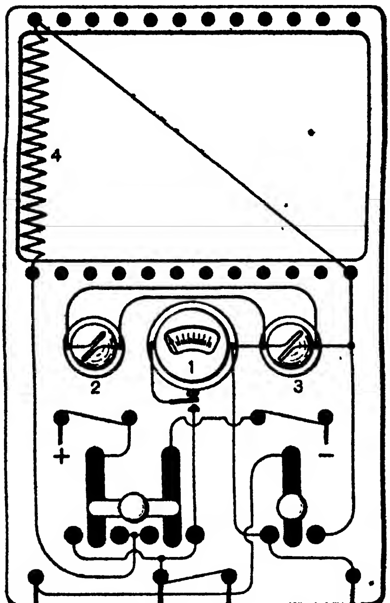

Fig. 109.

Marconi marine type charging switchboard.

1. Voltmeter
2 and 3. Lamp resistances
4. Coil resistances

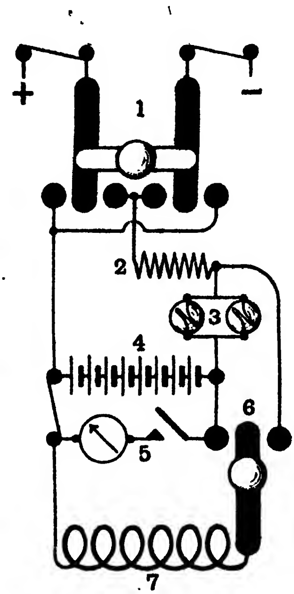

Fig. 110.

1. Double pole switch
2. Coil resistances
3. Lamp resistances
4. Accumulators
5. Voltmeter
6. Single pole switch
7. Primary of coil

Extension to Marine Type Switchboard

On some installations an auxiliary switchboard is installed, which enables the accumulators to be charged at a quicker rate (12 amp.), and also makes the board

adaptable to voltages of 80–100 and 120. Provision is also made for discharging the accumulators.

The internal connections of the extension board are shown in Fig. 111, it will be seen that it consists of four resistance coils (connected in series), and a double-throw switch mounted on a slate panel. To charge the accumulators at maximum rate the double-throw switch should be put in the charge position after the charging switch on the main board has been closed in the usual way (that is, put to the side where the lamps are least bright).

The effect of closing the auxiliary switch is to put the coil resistance in parallel with the lamps, thus materially reducing the resistance of the circuit.

To discharge the accumulators, the switch on the auxiliary board should be put to the discharge side, all switches on the main switchboard being in the off position.

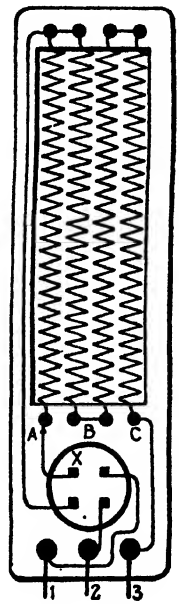

FIG. 111.
Auxiliary switchboard.

Connect X to A on 120. Volt Cct.

Connect X to B on 100. Volt Cct.

Terminal 1 is connected to right of coil resistance on main board.

Terminal 2 is connected to left hand side of bottom fuse on main board.

Terminal 3 is connected to right hand lower terminal on main board.

CHARGING SWITCHBOARD (TYPE 2)

This switchboard, the connections of which are shown in

Fig. 114, performs all the functions of the number 1 type switchboard plus the auxiliary panel, which it supersedes. By short-circuiting the first four coils on the bottom row, the board can be adapted for use on 100-volt supply circuit; this can be done by connecting a conductor of suitable cross-sectional area between terminals 1 and 2.

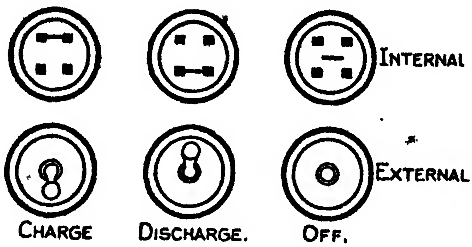

FIG. 112.

Showing switch on auxiliary board.

By short-circuiting the first eight coils on the bottom row, the board can be used on an 80-volt circuit, this can be done by connecting terminal 1 to terminal 3. The board, as it is shown in the diagram, is intended for use on a supply circuit of 120 volts. To charge the accumulators the double-pole double-throw switch is placed in the position in which the lamps are least bright. To charge at the higher rate (12 amp.), the tumbler switch on the left of the board should, in addition, be put to the charge position.

To discharge the cells the tumbler switch on the left of the board should be put to discharge, all other switches being in the off position.

To work the induction coil from the accumulators,

the tumbler switch on the right should be put in the position marked accumulators. To work the coil from the supply circuit, the switch should be put in the position marked mains.

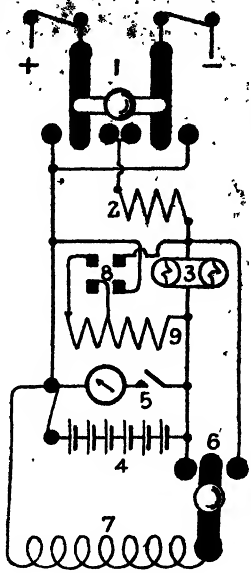

FIG. 113.

Showing circuits of charging switchboard and auxiliary panel.

1. D.P.D.T. switch.
2. Coil resistance on main switchboard.
3. Lamp resistance.
4. Cells.
5. Volt-meter.
6. Single pole switch.
7. Primary of induction coil.
8. Switch on auxiliary panel.
9. Coil resistance on auxiliary panel.

THE MULTIPLE TUNER

The Marconi multiple tuner, which is one of the three-circuit type described in the chapter on receiving apparatus, and the magnetic detector are usually used as the receiving apparatus with the $1\frac{1}{2}$ kw. set, although on some stations the Fleming valve and the special tuner with which it is incorporated are in use. Fig. 115 shows the internal connections of the multiple tuner.

It will be seen that as the three coupled switches are moved round, the effect is to add capacity (and in the case of the primary circuit inductance) to the three circuits and so to increase the wave-length range. For instance, when the switch is in position 1 a small condenser of fixed capacity is put in series with the variable condenser in each of the three circuits and only half the turns on the primary coupling.

coil are in circuit, when the switch is in position 2 the small condensers are cut out of circuit. Position 3 increases the inductance of primary coil and puts condensers of fixed capacity in parallel with the variable

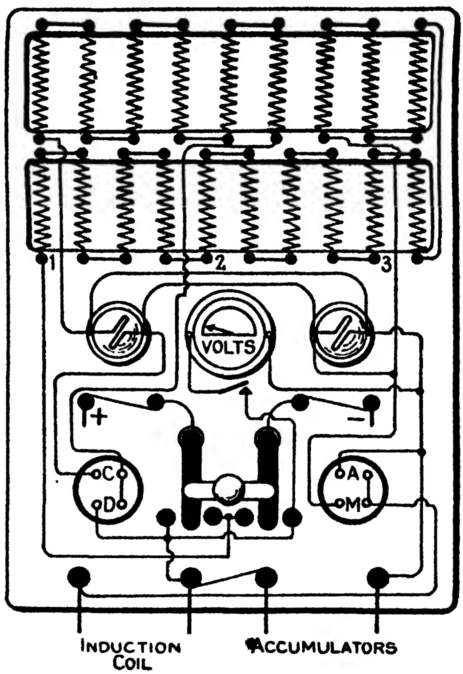

FIG. 114.

Charging switchboard. (Type 2.)

condensers in the intermediate and detector circuits. Position 4 puts still larger condensers in parallel with the variable condensers in the intermediate and detector circuits and increases the inductance of the

primary coil to its maximum value. Fig. 117 shows the composition of the three circuits for the various

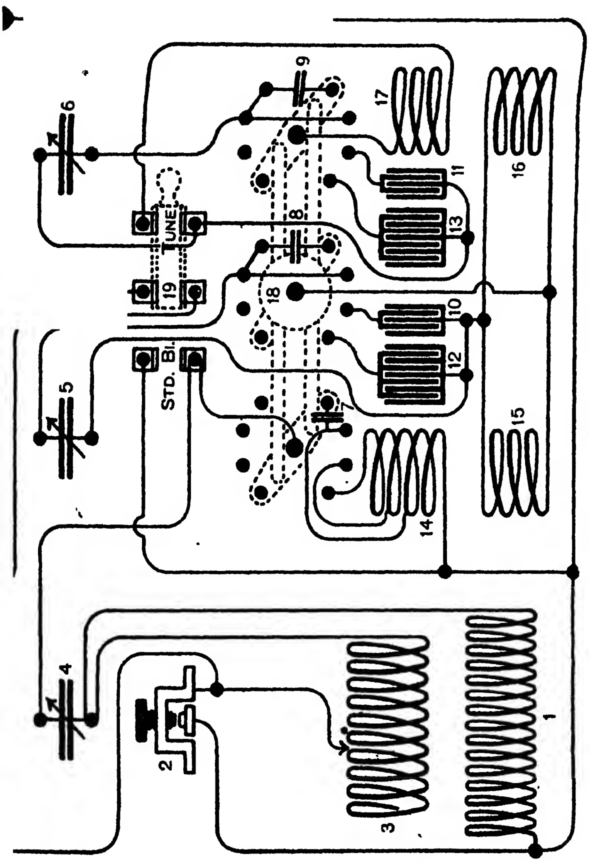

FIG. 115.—Circuits of Marconi multiple tuner.

1. High self-inductive shunt.
2. Micrometer spark-gap.
3. Aerial tuning inductance.
4, 5 and 6. Variable condensers.
7, 8 and 9. Small fixed capacity condensers.
10, 11, 12 and 13. Fixed capacity condensers.
14. Primary coupling coil.
15 and 16. Coils of intermediate circuit.
17. Coil of detector circuit.
18. Multiple tuning switch.
19. Change-over switch.

positions of the switch. It will be noticed that the inductance of the secondary circuit consists of two

coils, this is to facilitate the coupling of the circuit to the primary and to the detector circuit. Both the

Photo FIG. 116. *Topical*

Operating cabin s.s. *Franconia.*

coils are carried on a shaft which terminates in a handle seen to the right in Fig. 118 and the coupling

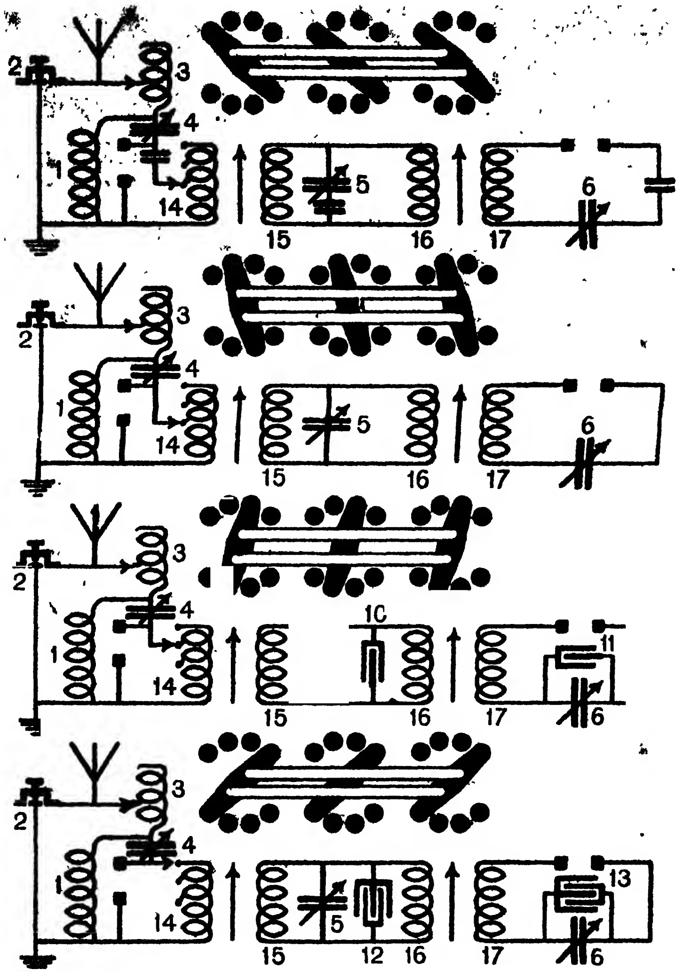

FIG. 117.

Reference numbers as in Fig. 115.

between the circuits is thus varied simultaneously. On top of the tuner (Fig. 118) is a change-over switch which enables the detector to be connected in the third circuit for tuned reception or places it directly in connection with the aerial circuit, which is the stand-by position; in this position the detector will respond to a comparatively large range of wave-lengths. When working on the stand-by position the multiple tuning-switch should be in number 1 position, the small fixed capacity condenser will then act as a blocking condenser to the primary of the magnetic detector. Referring to the diagram of the tuner, 1 is a high self-inductive shunt to earth; its purpose is to prevent the accumulation of an electro-static charge on the aerial: 2 is a micrometer spark-gap and serves the same purpose as a lightning arrester and protects the primary circuit from the transmitter when it is in action. Terminals A and E are connected to the top and bottom plates of the earth arrester, when the transmitter is in action sparks pass across the gap and the primary circuit of the tuner is thus shorted out. When the transmitter is not in use the circuit from aerial to earth is complete through the primary coil of the tuner. It will thus be seen that the receiver can be left connected to the aerial and a change-over switch is not needed, also it permits the receiving operator to break in or interrupt the sending operator during the course of transmission if necessary.

The terminals marked D, D are connected to the terminals marked A and E on the detector. Fig. 119 shows connection between tuner and detector. The magnetic detector has been fully described in the chapter on detectors and it only remains to say that

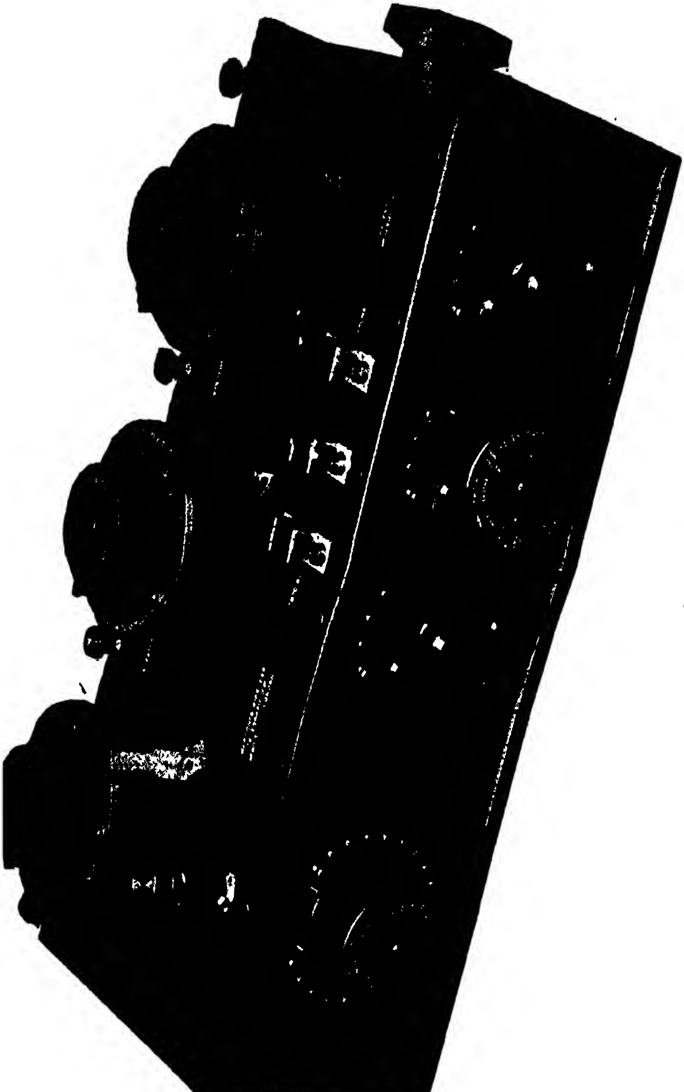

FIG. 118.
Marconi multiple tuner.

the telephone receiver is short-circuited before the power circuit of the transmitter is closed by means of an extra pair of contacts which are closed by a small arm which projects from the lever of the Morse key.

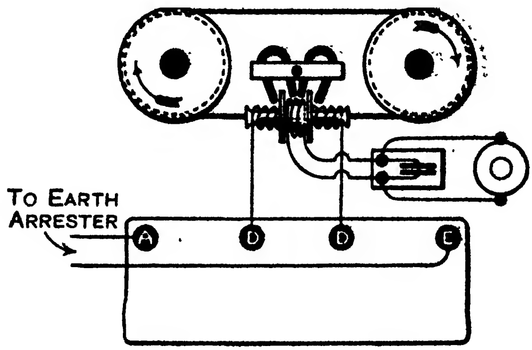

Fig. 119.

Connections between multiple tuner and magnetic detector.

Telephone Condenser

The telephone condenser shown in Fig. 120 is variable in seven steps by means of three plugs. This condenser, together with the telephones which have inductance and resistance form an oscillatory circuit, and the purpose of the condenser is to enable us to tune the circuit to the *spark* frequency of the transmitter or to one of the harmonics of that frequency.

Adjustment of Multiple Tuner

For stand-by working, the aerial circuit of the tuner should be adjusted to the 600-metre wave, as this is the standard wave-length of most ship stations.

When the tuner is connected across an earth arrester spark-gap, the aerial tuning inductance of the transmitter, and the secondary winding of the oscillation transformer, will form part of the receiving circuit. The inductance of these coils, which are in series with

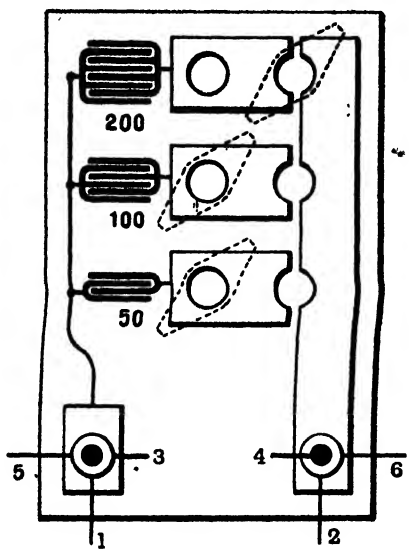

FIG. 120.

Connections of telephone condenser.

1 and 2 to secondary of detector. 3 and 4 to telephones. 5 and 6 to short-circuiting contacts on Morse key.

the aerial, has already adjusted the circuit to the 600-meter wave, the aerial tuning condenser should, therefore, be kept at short circuit, and the aerial tuning inductance of the multiple tuner at zero. Fig. 121 shows the composition of the aerial circuit of the tuner for stand-by working.

To change over to the tuned side the procedure is as follows: The aerial circuit of the tuner having been adjusted to the same wave-length as the transmitter which is making the call, an estimate should be made as to the wave-length being received, and the multiple

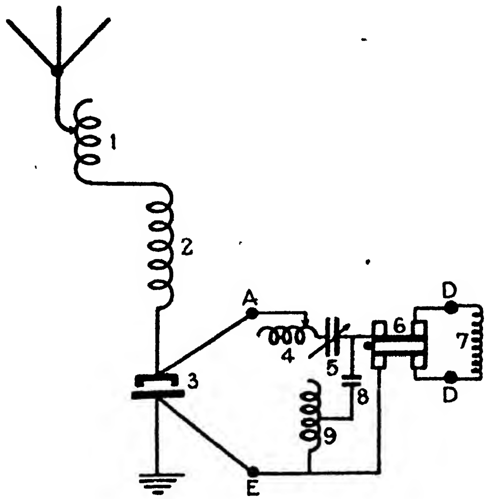

FIG. 121.

Showing composition of circuit for stand-by working.

1. A T I of transmitter.
2. Secondary of oscillation transformer.
3. Earth arrester.
4. Aerial tuning inductance of tuner.
5. Aerial tuning condenser.
6. Change-over switch.
7. Primary of magnetic detector.
8. Fixed capacity condenser.
9. Coupling coil.

tuning switch set accordingly. If it has been necessary to insert a large amount of the aerial tuning inductance in order to bring the aerial circuit to resonance with the calling transmitter, a long wave is being received and the multiple tuning switch should

be placed on the third or fourth stop. If the aerial tuning inductance is at zero and the aerial tuning condenser set at a low value, to secure resonance with the calling transmitter, a short wave is being received, and the switch should be set on stop 1 or stop 2. Stop 2 covers both the 300 and the 600-meter wave, and therefore will be most frequently used. Having set the multiple switch on the appropriate stop, put the change-over switch to the tune side, and vary the condensers in the intermediate and detector circuit together, until the signals are at their maximum strength. The coupling between the three circuits should then be loosened a few degrees and the three circuits readjusted to resonance, this operation being repeated until the desired freedom from interference is attained. It is most convenient to start the adjustment of the intermediate and detector circuits with the condensers at zero capacity and gradually to increase it till resonance is attained. The coupling is tight when the intensifier handle is set at 90°, as the handle is turned toward zero the coupling is loosened.

If the setting of the aerial tuning inductance and the setting of the aerial tuning condenser indicate that a 600 meter wave is being received, the condensers in the intermediate and detector circuits may be at once adjusted by reference to the calibration chart, and all that is then necessary to change over to the tune side is to set the multiple switch on stop 2, put the change-over switch to tune, and adjust the coupling.

The Multiple Tuner used as a Wave Meter

The intermediate circuit of the multiple tuner is a calibrated circuit, that is, the wave-length for each

setting of the variable condenser, on each of the stops of the multiple tuning switch, has been ascertained and recorded on a chart; the tuner can therefore be used to measure wave-lengths. To measure the wave-length of a distant transmitter, tune in the signals with as loose a coupling as possible, note the setting of the multiple tuning switch and the setting of the intermediate condenser and refer to the chart. The chart is arranged in three columns, the second column gives the settings of the multiple tuning switch, the third column gives the settings of the intermediate condenser and the first column the wave-lengths corresponding to the settings. It should be noted that the readings on the chart are correct only when the coupling between the tuner circuits is very loose (not more than 10°). To measure the wave-length of the transmitting circuits, the tuner should be disconnected from the earth arrester gap, and the parts of the tuner which are normally in the aerial circuit transformed into a closed oscillatory circuit by the connection of a loop of wire between the aerial and the earth terminals of the tuner. This loop of wire is utilized to effect coupling between the tuner and the transmitter, the coupling should, of course, be very loose, a distance of 10 or 12 ft. between the loop and the oscillatory circuits of the transmitter, giving a sufficient coupling to produce audible signals with the intensifier handle at 10°. The transmitter is set in action and the oscillations tuned in in the usual way on the tuned side. When using the tuner as a wave meter to measure the transmitted wave-length, the aerial tuning condenser must not be short-circuited, as it now forms the capacity in a closed circuit.

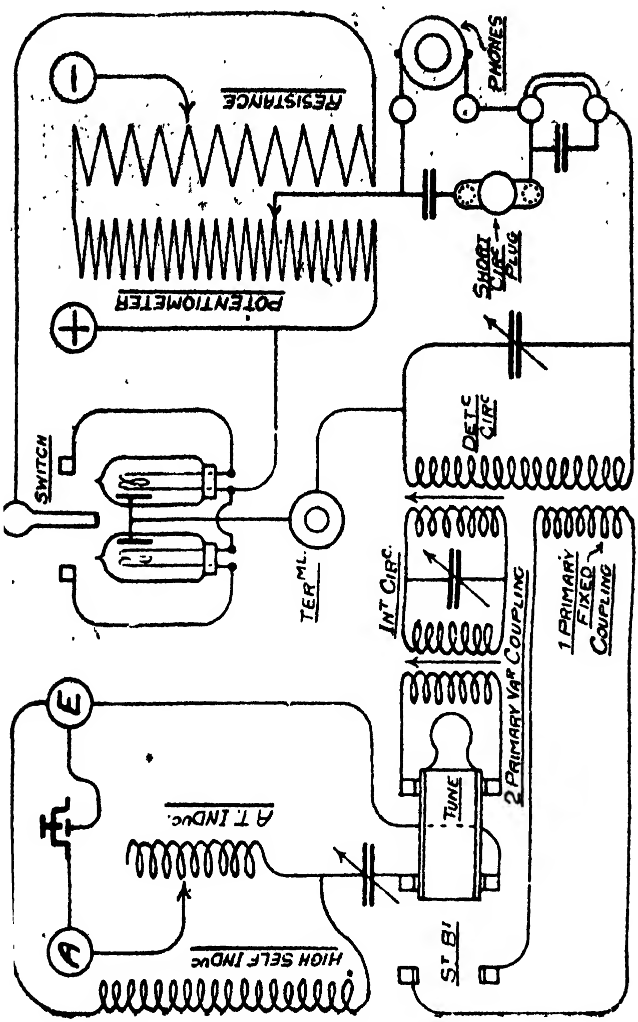

FIG. 122.
Fleming valve tuner.

FLEMING VALVE TUNER

The action of the Fleming valve has already been described in a previous chapter, but the connections of the special tuner with which it is incorporated may be of interest. Like the multiple tuner, it is of the three-circuit type, but the change-over switch simply substitutes different primary coils. The primary coil

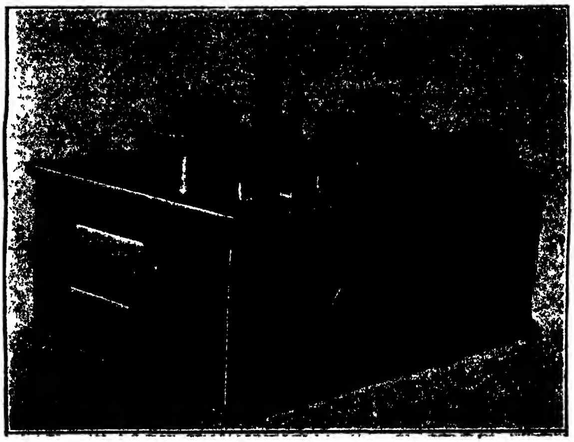

FIG. 123.

Fleming valve tuner.

in use on the stand-by position is closely coupled to the detector circuit and when the switch is put over to the tune position a primary coil coupled to the intermediate circuit, the coupling of which can be varied, is substituted. The high self-inductive shunt and the micrometer gap are connected in the same position and serve the same purpose as in the multiple tuner. Fig. 122 is a diagram of the connections. It will be seen that

two valves are provided and a switch which changes the battery from onè to the other. The purpose of the variable resistance is to regulate the current supplied to the filament of the valve.

Crystal Receivers

A carborundum crystal detector is sometimes supplied in addition to the magnetic detector. The third circuit of the multiple tuner is unsuitable for use with a potential actuated detector, as the capacity predominates over the inductance, and the terminal voltage at the condenser would therefore be low. To enable a carborundum crystal to be efficiently used with the multiple tuner an adaptor is necessary. This consists of a coupling coil which is connected to the tuner in place of the primary winding of the magnetic detector, and to which is coupled a coil, having large inductance, a variable condenser of small capacity being connected across it. The detector is connected across this condenser as shown in Fig. 124.

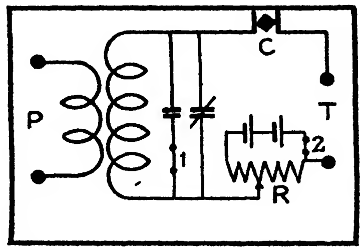

FIG. 124.

Single crystal receiver, for use with multiple tuner.

P. Coupling coil which forms part of third circuit of multiple tuner.
C. Carborundum crystal—
1. Pin to connect up fixed capacity condenser.
2. Pin to disconnect cells when not in use.
R. Potentiometer.
T. Telephone terminals.

It will be seen that there are four oscillating circuits when this arrangement is in use. The wave-length range of the fourth circuit is increased by means of a

condenser of fixed capacity, which can be connected in parallel with the variable condenser by the insertion of a copper pin or disconnected by its withdrawal.

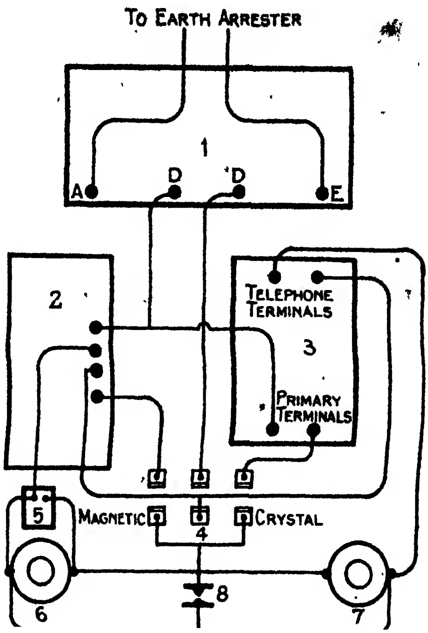

Fig. 125.

Showing connections between multiple tuner, magnetic detector, and crystal receiver.

1. Multiple tuner.
2. Magnetic detector.
3. Crystal receiver.
4. Change-over switch.
5. Telephone condenser.
6. Low resistance telephones.
7. High resistance telephones.
8. Short-circuiting contacts.

The telephone receivers used have a total resistance of about 8,000 ohms. A double-pole double-throw switch is provided in order that the change from one

etector to the other may be quickly made. The onnections between the detectors and the tuner are hown in Fig. 125.

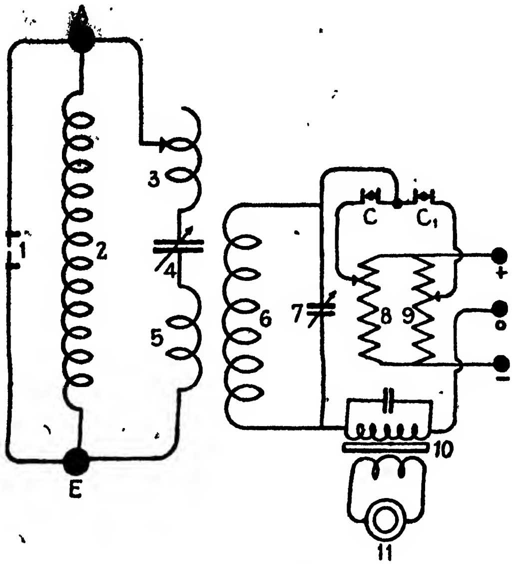

FIG. 126.

Balanced crystal receiver.

1. Micro-meter gap.
2. High self-induction shunt.
3. Aerial tuning inductance.
4. Aerial tuning condenser.
5. Primary coupling coil.
6. Secondary coupling coil.
7. Detector tuning condenser.
8 and 9. Potentiometers.
10. Step-down transformer.
11. Low resistance telephones.
C, C_1. Crystals.

Balanced Crystal Receiver

The action of the balanced crystal receiver has eady been explained in Chapter V. Fig. 126 ows the connections of the instrument as supplied

by the Marconi Company. The composition of the aerial circuit is the same as that of the multiple tuner, and the circuit is protected in the usual way, by means of a micrometer spark-gap and high self-inductive shunt. The wave-length range of the detector circuit can be varied by altering the inductance, which is variable in three steps. If only one crystal is inserted, the apparatus can be used as an ordinary crystal receiver, for balanced crystal working both crystal must be inserted and in such a direction that they rectify oppositely.

CHAPTER VII

THE POULSEN SYSTEM

The Poulsen Arc—The Tikker Receiver—Photographic Recorder—High-speed Transmitter—Tone Sender

The Poulsen system is based on the discovery of Mr. Duddell that if a direct-current arc is shunted by a circuit containing capacity and inductance there will be established in the circuit electrical oscillations, the frequency of which depends upon the value of the inductance and capacity. The reason of this is that unlike a metallic conductor the arc does not follow Ohm's law and the curve showing the relation between current and terminal voltage is not a straight rising line, but has what is termed a falling characteristic (Fig. 127)—that is to say, if the current through the arc be increased the potential difference at its terminals will drop. Suppose now that a circuit with capacity and inductance in series is placed across the terminals of an arc, the condenser will charge, and in doing so, the current through the arc being lessened, the potential difference at its terminals will increase and charge the condenser to a still higher voltage. After the capacity is fully charged the current through the arc

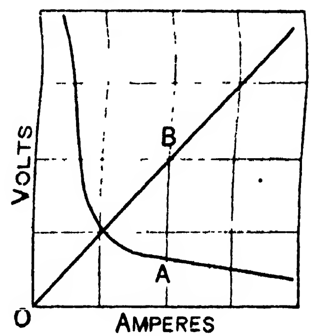

FIG. 127.

A=Arc. B=Metallic conductor.

will increase, and owing to the drop in voltage which it causes the condenser will discharge across the arc, and the discharge will, if the resistance is small, be oscillatory. In order to obtain oscillations of considerable energy, Mr. Duddell found that it was necessary to use a capacity of the order of 1 microfarad, and with a capacity of this magnitude it was not

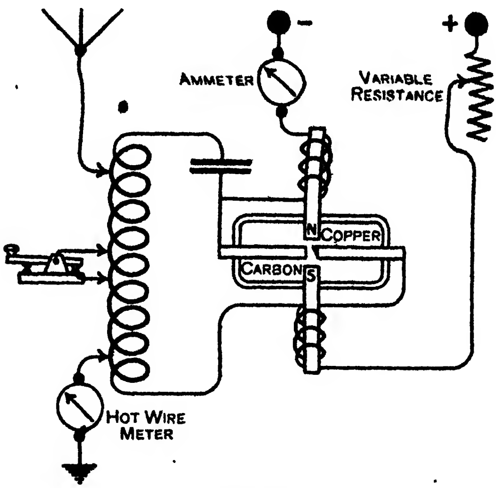

FIG. 128.
Poulsen arc transmitter.

possible to obtain the very high frequencies needed for Radio-Telegraphy.

Poulsen's great discovery was the effect of a hydrogen atmosphere which by cooling the arc increased the steepness of its characteristic curve, and also the use of a very powerful magnetic field which enabled him to get a high terminal voltage. By the use of the arc burning in a hydrogen atmosphere, and the powerful transverse magnetic field, he was able to use

a small capacity and thus get oscillations of the frequencies useful for Radio-Telegraphy and at the same time powerful. The practical construction of the Poulsen arc is as follows: the anode is made of copper and the end takes the form of a beak (Fig. 128). The cathode is of carbon about 1 in. in diameter, the arc striking between the copper beak and the edge of the carbon. The carbon is fitted in a holder which is slowly rotated by means of a small motor, and as it burns away a fresh surface is presented and *the length of the arc kept constant.* The arc-length is also adjustable by means of a screw fitted to the copper electrode.

The electrodes are taken through insulating sleeves in the sides of a water-cooled metallic chamber which is also flanged on the outside to assist the cooling. Through the sides of the chamber, and transversely to the electrodes, pass the pole-pieces of a powerful electro-magnet which blows the arc out into a loop, the winding of the magnets being in series with the arc also serve as choking coils and prevent the oscillations from passing back into the supply circuit. The chamber in which the arc burns is supplied with hydrogen through a tube let into its base and after passing through the chamber escapes through an outlet at the top and is conveyed away by means of a tube connected to it. The arc is connected across a 500 volt direct-current supply and across it is shunted the primary circuit, which consists of a condenser and an inductance in series. The aerial is connected to one point of the inductance and the earth wire to another. Signalling is effected by shorting through the Morse key a turn or two of the inductance which

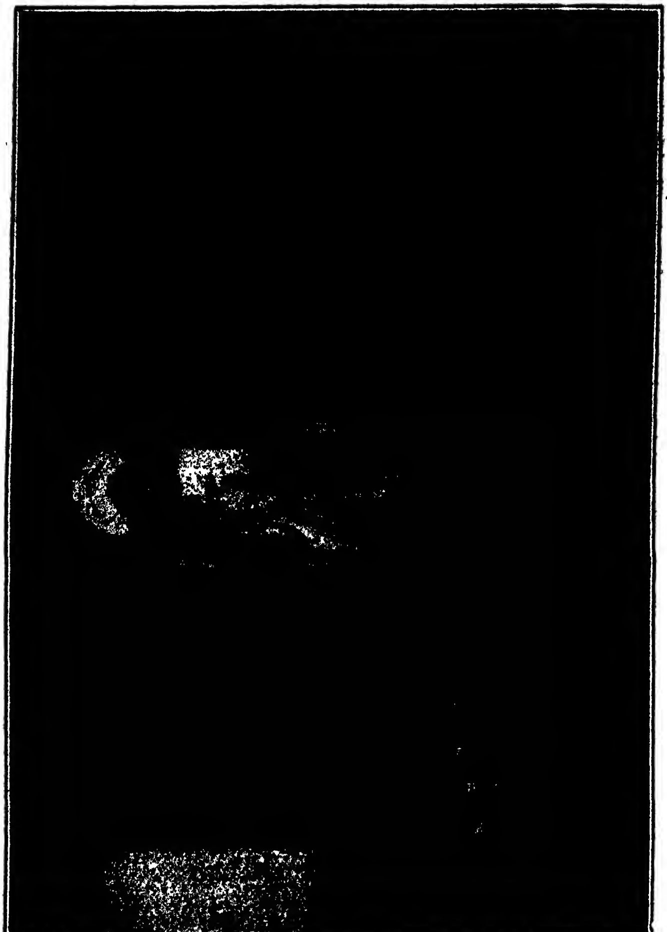

Fig. 129.
Poulsen arc.

alters the wave-length and throws the transmitter in and out of tune with the receiver, a difference of about 5 per cent. being sufficient. As energy is supplied to the aerial at every swing the oscillations emitted from the Poulsen generator are continuous and undamped, or practically so. The receiving arrangement used in conjunction with the Poulsen transmitter is unlike that of any other system inasmuch as no detector is made use of, but the received

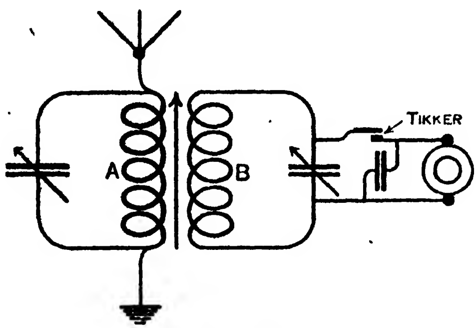

FIG. 130.
Poulsen tikker receiver.

energy accumulated in a condenser and discharged at intervals through the telephone by means of a piece of apparatus which the inventor has named a tikker. Fig. 130 shows diagrammatically the receiving circuits. A is the primary coil with variable condenser across its terminals to adjust the tuning; coupled to this coil is the secondary circuit B, which consists of a coil and a variable condenser; across the terminals of this condenser is joined a mica condenser of fairly large capacity and the tikker, which is an intermittent contact formed by two gold-plated brass wires crossing

each other at right angles, one of them being mounted at the end of a small electro-magnetic make and break

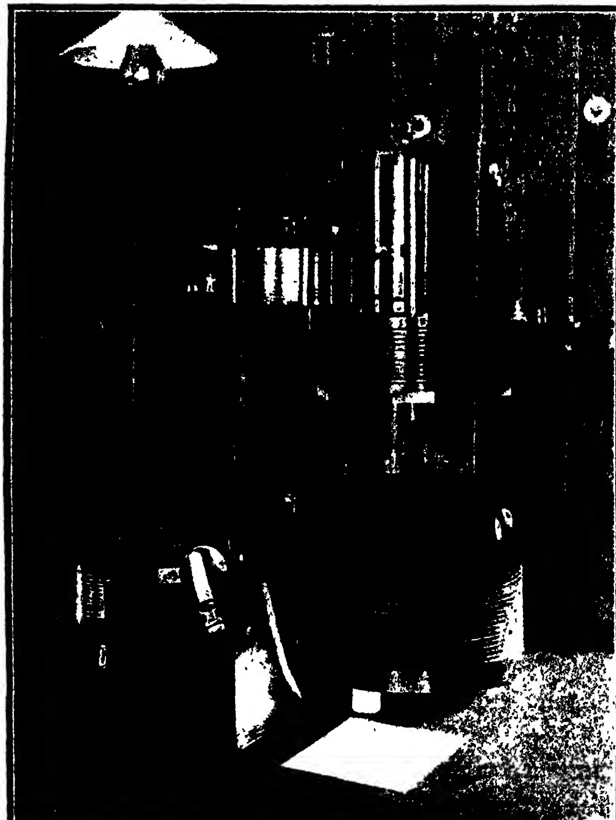

Fig. 131.
Poulsen tikker receiver.

similar in construction to a trembler bell. The telephone, which is of low resistance, is joined across the mica condenser. The action of the tikker is as follows :

the primary is first tuned to the sending station and the secondary tuned to the primary. *During the* intervals when the tikker contacts are open the secondary circuit is left free to resonate up, and the energy of many oscillations thus accumulated when the tikker contacts close, the circuit, owing to the added capacity of the mica condenser, which is now in parallel, will oscillate to a lower frequency. The opening of the tikker contacts will be determined by the presence or absence of a current across them, as this determines the conductivity of the small gap between the wires as the tikker starts to open. It will thus be seen that when the current is passing through zero the mica condenser, charged as it is with the greater part of the energy, will be disconnected from the secondary circuit and discharge through the telephone.

The coupling between the primary and the secondary is very loose and full use is thus made of resonance, the tuning being so sharp that a difference of 4 or 5 per cent. in wave length is sufficient to render the signals inaudible. The tikker method, although one of the most sensitive means known for detecting electrical oscillations, labours under the disadvantage that it is not able to receive signals from the ordinary spark transmitters which give out damped and discontinuous oscillations.

Photographic Recorder

Valdenar Poulsen in conjunction with his assistants has devised a very sensitive recorder capable of recording signals at a high rate. It consists of a string galvanometer composed of a very powerful

electro-magnet between the poles of which is stretched an exceedingly fine gold wire. The image of the wire is by means of a microscope magnified and thrown on to a moving strip of sensitised paper. If now signals actuate the thermo-detector it will pass a current through the fine wire to which it is joined, and the wire

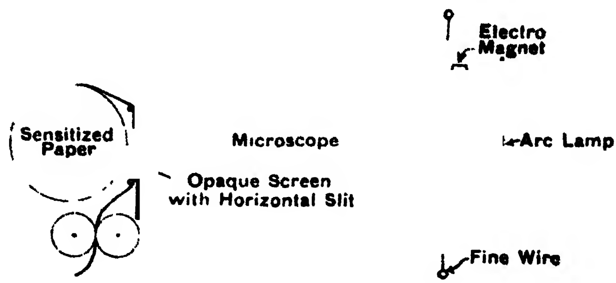

FIG. 132.

Poulsen photographic recorder.

will be deflected and the position of its image on the tape will be altered; it will thus be seen that the recording of a dot or a dash depends upon the time which the wire is displaced from its position or rest.

FIG. 133.

Specimen of slip—(104 words per minute).

The tape after recording the signals passes through a tank containing developer and then through one in which is contained the fixing solution. Fig. 132 shows the arrangement of the apparatus and Fig. 133 a specimen of the tape.

Poulsen High-speed Transmitter

The high-speed transmitter is arranged to take messages prepared on perforated slip by a modified Wheatstone perforator. The perforator is modified by the removal of one punch each from the sets controlled by the dash lever and by the dot lever, so that a dash consists of a single perforation on the upper part of the slip and two centre perforations, whilst a dot

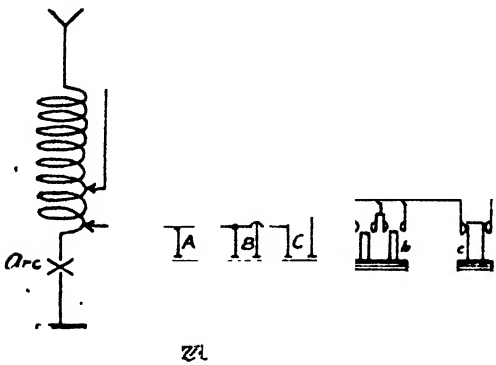

Fig. 134.

consists of a single perforation in the lower part and a single centre perforation. The transmitter (designed by Professor Pedersen) is arranged in drum form, and the essential principle of its electrical action is as follows—

A mark is signalled by short-circuiting a portion of the aerial inductance helix, and this short circuit involves the closing of two separate contacts in series. Any sparking that occurs is therefore at the latter of the two makes and the former of the two breaks. These sparking contacts, determining the final make

and break of the short-circuit current, are heavy, and do not depend on the punched slip for their operation.

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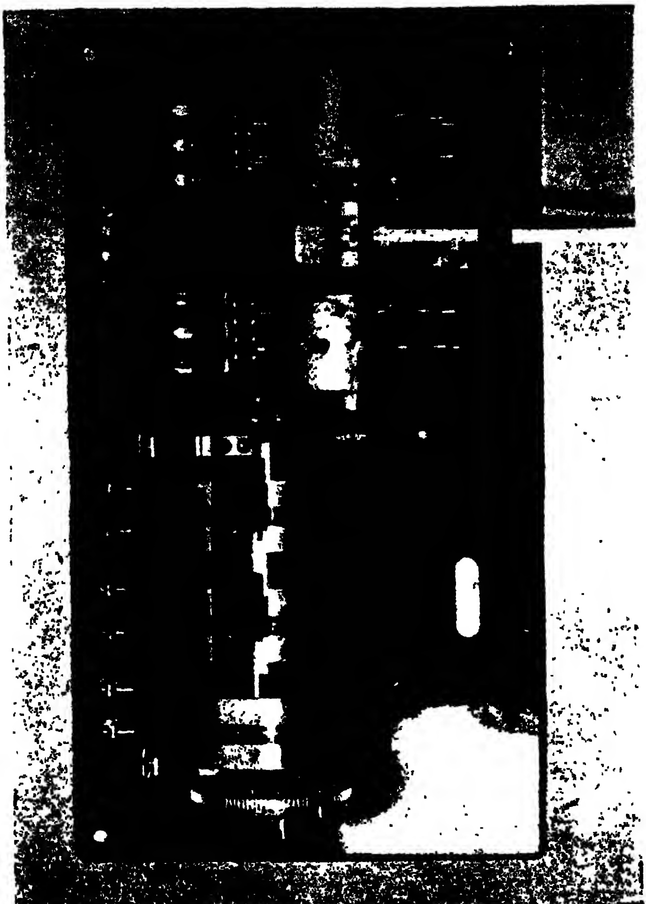
The slip controls the first make and second break contacts only, which, as they are not subject to sparking,

may be of light construction. Fig. 134 is a diagrammatic representation of the transmitter. A, B, C are



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the heavy-contact drums; while *a*, *b*, *c* are rows of radial pins thrust outwards by the operation of the

punched strip, and constituting the sparkless first line of contacts. C and *c* control the dots, while A and *a*, and B and *b* control the dashes. Dashes beginning on even centre perforations utilise A, *a*, while dashes on the odd perforations utilise B, *b*. Figs. 135 and 136 show the appearance of a recent design of the machine.

The three drums A, B, C, are fitted with copper-marking segments and glass-spacing segments, and copper brushes bear against them.* The pins *a*, *b*, *c*, projecting radially from the rotating drums or rings, are thrust outwards from the drum, so as to bridge the fixed spring contacts "knife-switch" fashion as they pass, whenever small levers controlled by the plunger-pairs are projected through the dot-and-dash perforations in the paper strip. It will thus be seen that the controlling contact pins *a*, *b*, *c* are set in position in advance, to accord with the dot-and-dash perforations in the punched tape, and retain their positions during a part of the evolution of the drums until they have passed the spring contacts. They are then automatically withdrawn to the gradually normal positions.

The machine has been practically operated up to speeds of 300 words per minute, and it then appears to operate as efficiently as at the lower speeds. The Company have a number of machines under construction, in which sundry improvements are embodied.

It should be mentioned that in one respect the high-speed transmitter operates differently from the Morse key. Whereas the latter "marks" with the longer wave and "spaces" with the shorter, the former

* In the later form of transmitter shown in 6 and 7, air space insulation is provided between the segments.

reverses this procedure, and the dots and dashes on the received slip appear as short and long periods of zero deflection. That is, the receiving apparatus remains quiescent during the marking periods, and is deflected during the spacing periods. The machine is covered by British patent No. 25190, A.D. 1909.

This description of the Poulsen high-speed transmitter is reproduced from The P.O. Electrical Engineers' Journal, by kind permission of the board of Editors.

The Tone Sender

For the continuous and undamped waves sent out by the Poulsen system to be heard by an *ordinary* spark receiver it is necessary that they should be cut up into rapidly alternating trains of marking and spacing waves. This is effected by connecting across the Morse key a rotary make and break driven at a high rate (900 to 1,000 contacts per second). The signals heard when such an arrangement is in use have a high musical note, but are not so strong as with the ordinary arrangement used in conjunction with the tikker receiver.

Beat Reception

The invention and perfecting of the three electrode valve, has made possible the reception of continuous and undamped oscillations without a tikker, by providing a simple and reliable means for generating in the circuits of the receiver high frequency currents. The action of the beat receiver is based on the fact, that if currents of two different frequencies are generated in the same oscillatory circuit, they combine and produce a third frequency equal to the difference

between them. Suppose for instance, that the frequency of the received oscillations is 500,000 per second and that the frequency of the locally generated oscillations is 499,000 per second, the current resulting from the interference of the two different frequencies will be 1,000 cycles per second. This frequency being within the limits of audibility, will actuate the telephone receiver. The circuit in which the local oscillations are generated, may be coupled to the aerial circuit of the receiver, an additional coupling coil being inserted in the circuit for the purpose.

CHAPTER VIII

TELEFUNKEN QUENCHED SPARK SYSTEM

The Transmitter—The Receiver—Calling-up Apparatus—Sound Intensifier

THE quenched spark method of exciting electrical oscillations, of which the Telefunken system is the most widely used, is based on the experimental work of Professor Wien.

While making experiments on two coupled circuits the primary or exciting circuit of which contained a very short spark-gap, he found that in place of the usual coupled waves only one existed, the wave-length of which was determined solely by the capacity and inductance of the secondary circuit. This is no doubt due to the fact that, when the spark-gap length is very short and the surface of the electrodes large, compared with it, the primary oscillations are rapidly damped out and cease to exist after two or three swings, and the energy being transferred to the secondary circuit and the coupling broken, the secondary circuit is left free to oscillate in its own natural frequency. Owing to the cooling of the gap and the consequent quick restoration of its high resistance there is no reflux back from the primary to the secondary as occurs in the ordinary coupled spark transmitters.

It will be seen that as the oscillation in the primary lasts for only a few swings the condenser losses in that circuit are a matter of comparatively small importance and it is therefore possible to use condensers having

mica or paraffin paper as a dielectric, thus effecting a great saving in space. The aerial used with a quenched spark transmitter is of the slow radiating type umbrella, or T-shaped, and the oscillations emitted are therefore feebly damped and persistent. Fig. 137

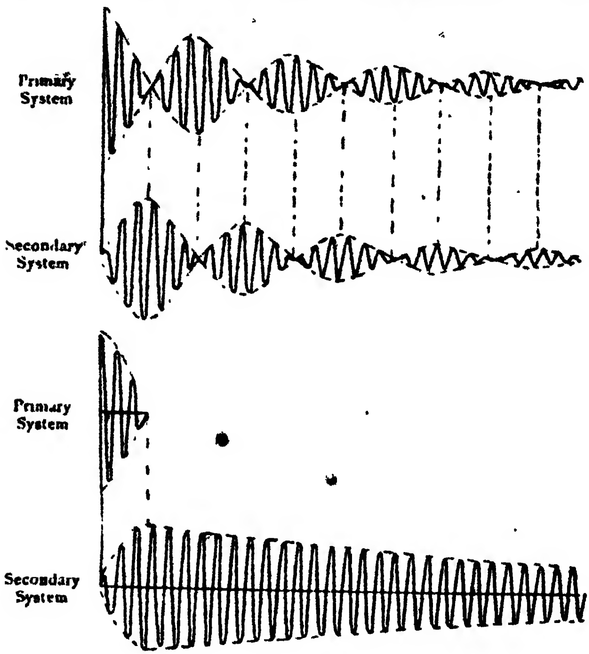


Fig. 137.

shows the character of the oscillations emitted from an ordinary spark transmitter and those emitted by a quenched spark transmitter. The efficiency of this method of generating electrical oscillations is very high, 75 to 80 per cent. being the efficiency claimed for the larger installations. As an example of the Telefunken system a description of their I.T.K. set is given

below. This set is built to give an oscillating energy in the aerial of about 1 kilowatt. Fig. 138 shows

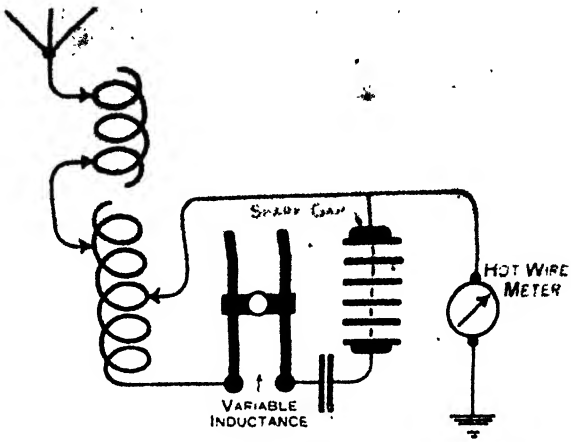


FIG. 138.

Oscillatory circuits. Telefunken transmitter.

the connections of the primary and secondary oscillating circuits. The closed circuit consists of quenched spark-gap, condenser—which has paraffined paper as dielectric—continuously variable inductance and a portion of the flat spiral inductance all in series. To two points on this latter are connected the earth and aerial leads, the latter through a lengthening coil and the former having included in it the usual hot wire ampère meter. The leads from the secondary of the alternating-current transformer are connected across the condenser. Figs. 139 and 140 are photographs of the set. The handle to left of Fig. 140 varies the inductance of the primary circuit. Fig. 141 is the aerial lengthening coil. When setting up a station the position of the clips for different wave-lengths are marked

and the inductance in primary circuit is then adjusted till the largest reading is shown on aerial meter.

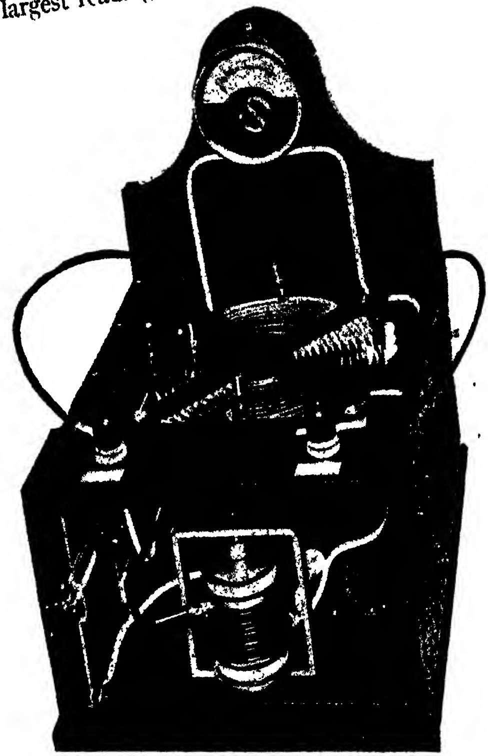


Fig. 139.
Telefunken transmitter (oscillatory circuits).

Current is supplied to the transformer, at 220 volts 500 cycles, by a motor generator, the direct-current side of the machine being built to suit the voltage of

the ship's mains. Fig. 143 shows the wiring of the switchboard, and Fig. 144 shows the combined starter and field regulating resistance. Fig. 145 shows the receiving apparatus, and Fig. 146 is a diagram of the

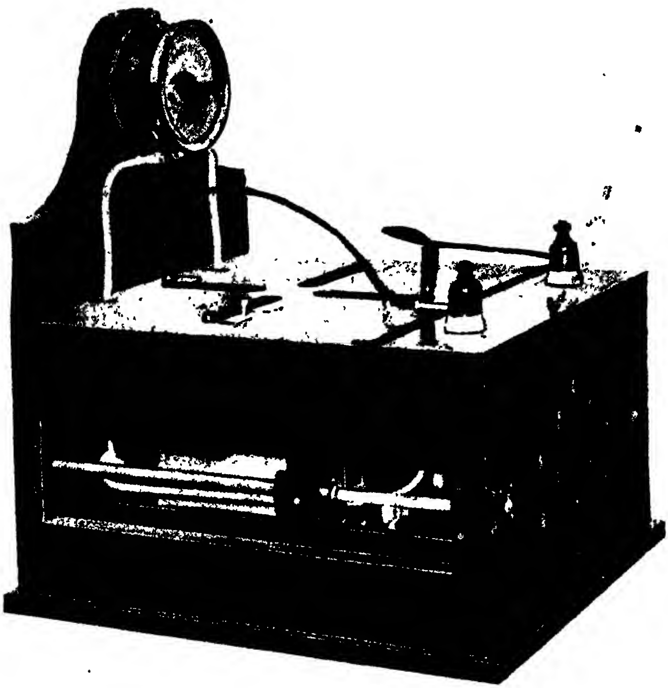


FIG. 140.
Telefunken transmitter.

connections. It will be seen that there are only two circuits in the tuner, the primary or aerial circuit and the detector circuit. This latter, owing to the inclusion of the detector in it, is practically an aperiodic circuit. The only adjustment, therefore, is on the

variable condenser in the aerial circuit. Arrangements are made for the transference of this variable condenser from the position shown in diagram to one across the coil; the tuner thus having a considerable wave-length range. In certain cases, for instance, on

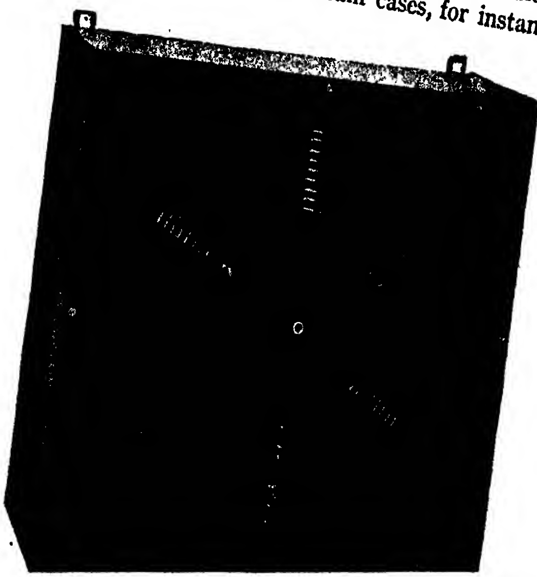


FIG. 141.
Aerial lengthening coil.

a land station having a very large aerial, say of umbrella type, it would not be possible to employ such a simple receiver to advantage because, owing to the close coupling between aerial and detector circuits, the enormous atmospheric disturbances sometimes met with would be carried with little diminution to the

detector and cause a serious reduction in its sensitiveness and perhaps damage it. This can be mitigated by the employment of a receiver of the three-circuit

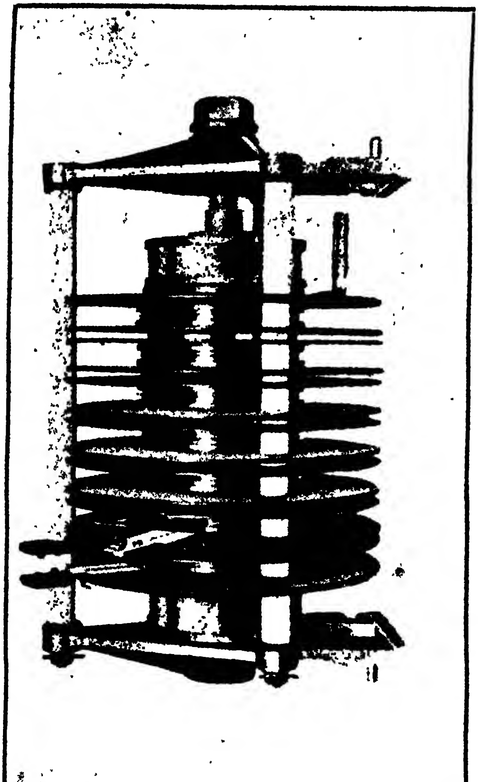


FIG. 142.
Quenched spark-gap.

type, the intermediate circuit of which is very feebly damped and which is loosely coupled to the aerial, and not very closely to the detector circuit. Fig. 147 shows a Telefunken tuner of this type. The coils of

the intermediate circuit are interchangeable and a considerable range of wave-lengths can thus be covered.

Calling-up Apparatus

The Telefunken Company supply with their stations a call-up device the construction of which is very ingenious. The following is a description of the

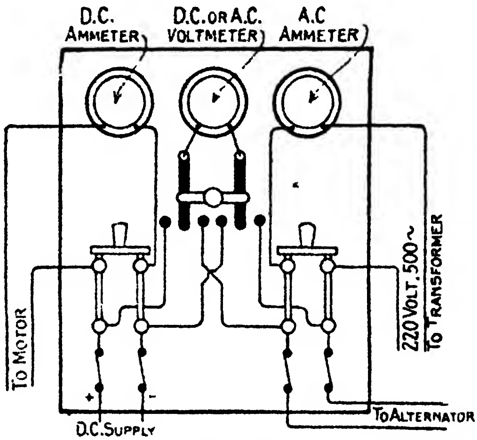


Fig. 143.

apparatus: the pointer of a well-balanced moving coil galvanometer, having a sensitiveness of 1×10^{-7}, is deflected by the current from the detector, if the current lasts for about ten seconds—*e.g.*, if the transmitter sends an uninterrupted dash for ten seconds. If the duration of the dash is much shorter, as when Morse signals are being sent, a suitable deflection is not obtained owing to the inertia of the galvanometer. When the pointer is deflected it engages in a toothed wheel which is continuously revolved by clockwork

and is depressed by it, thus closing a circuit containing a trembler bell which gives the alarm. The pointer is

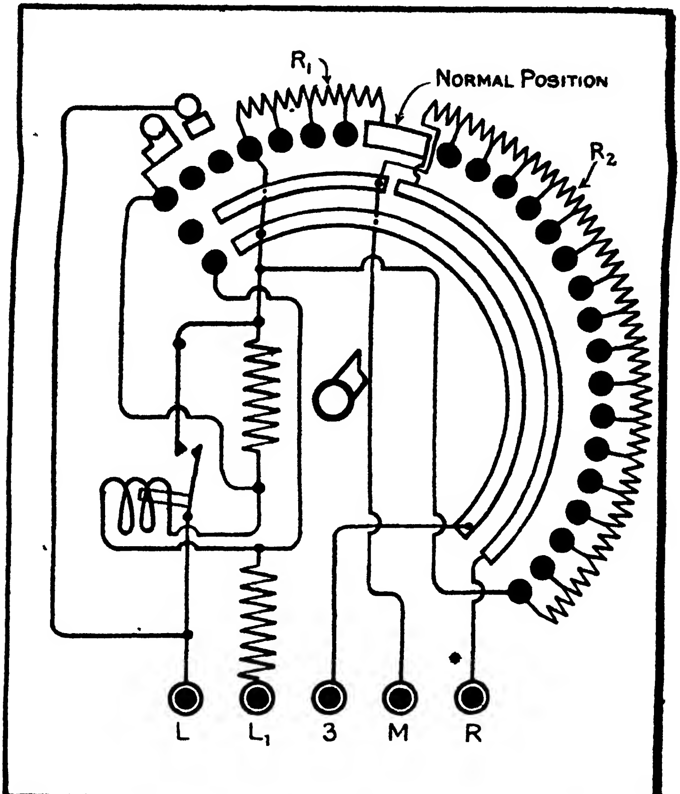


FIG 144.
Combined starter and field regulator.
R_1 Starting Resistance. R_2 Field Resistance.

released by means of a lever movement when the call is answered by the operator. Fig. 148 shows the apparatus as supplied to ship stations mounted in cardan suspension.

The loss of the *Titanic* brought forcibly home to the minds of the people the necessity for some kind of call

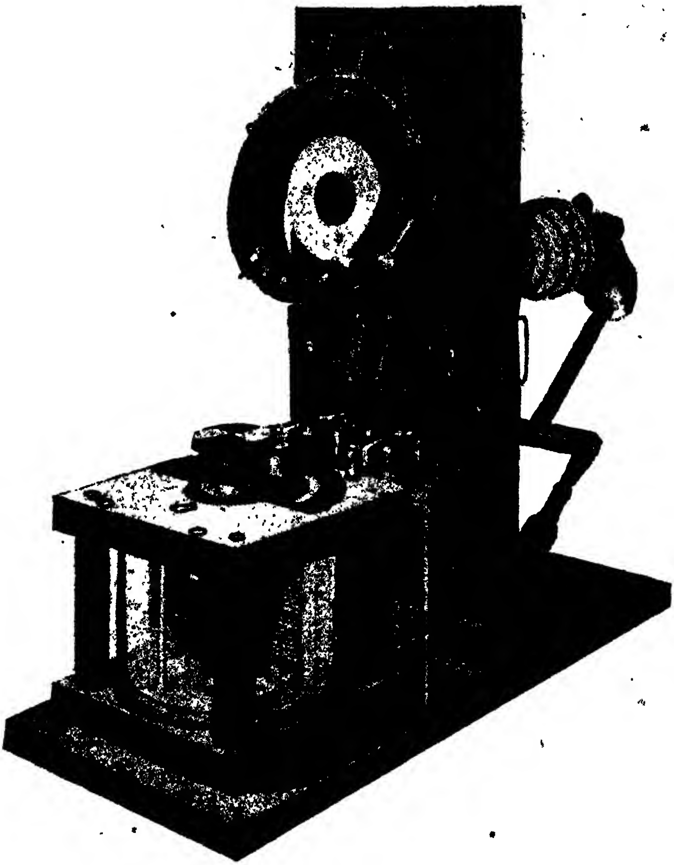


FIG. 145.
Telefunken receiver.

apparatus that would respond only to distress signals being installed on vessels carrying only one operator.

It appears to the writer that the above apparatus would, if certain alterations were made in the distress signal, meet all requirements.

If instead of the present S.O.S. a long dash were substituted, to be followed by the usual particulars as to the distressed vessel's position, etc., the ringing of the alarm bell would call the attention of the

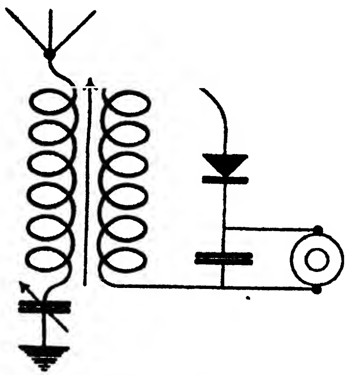


FIG. 146.

Circuits of Telefunken receiver.

operator, who would then take the particulars in the usual way.

Before any such device were adopted for the purpose it would, of course, have to undergo most searching tests as to its reliability.

TELEFUNKEN SOUND INTENSIFIER

The purpose of the sound intensifier is first, by means of mechanical tuning, to select signals of a given tone or spark frequency and then to intensify them. This is achieved in the following manner: the pulsating current which is given out by the

detector when it is actuated by signals passes through the coils of an electric magnet wound to a high resis-

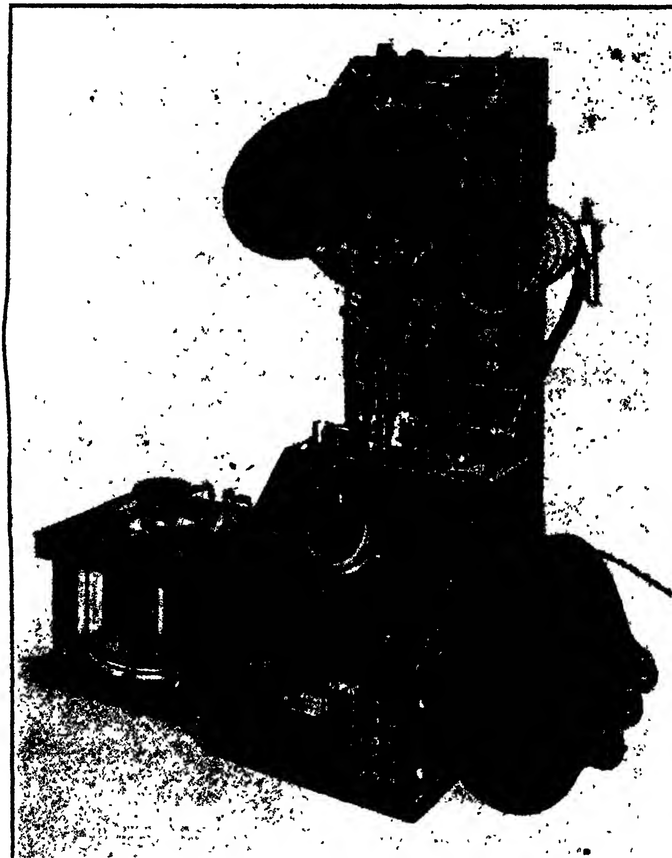


FIG. 147.
Telefunken receiver (three circuit type).

tance. The magnet is provided with a light armature with an accentuated natural period corresponding

with that of the tone to be received. Against the armature is pressed a microphonic contact in series with which is a dry cell and the winding of a similar magnet, the armature of which is stimulated into vibrations of greater amplitude by the intensified

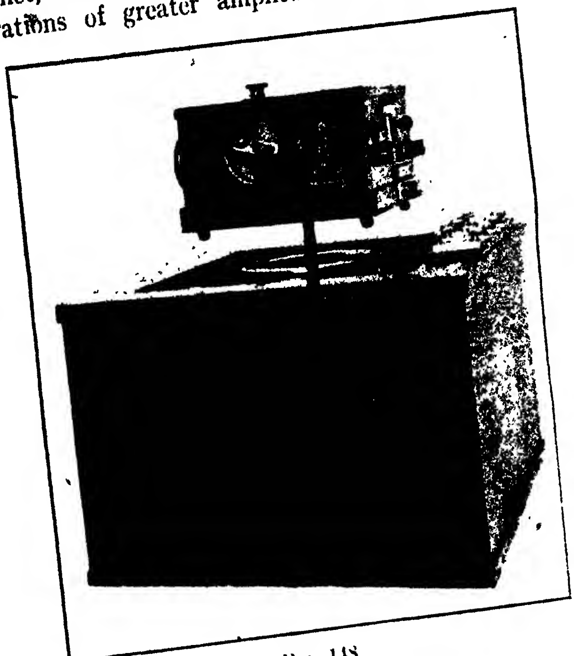


FIG. 148.
Telefunken calling-up apparatus.

current which is sent through its coils. It is the usual practice to step up the current three times and at the third intensification to pass the current through a loud-speaking telephone. With a triple intensification the current can be increased from 10^{-7} to 10^{-2}

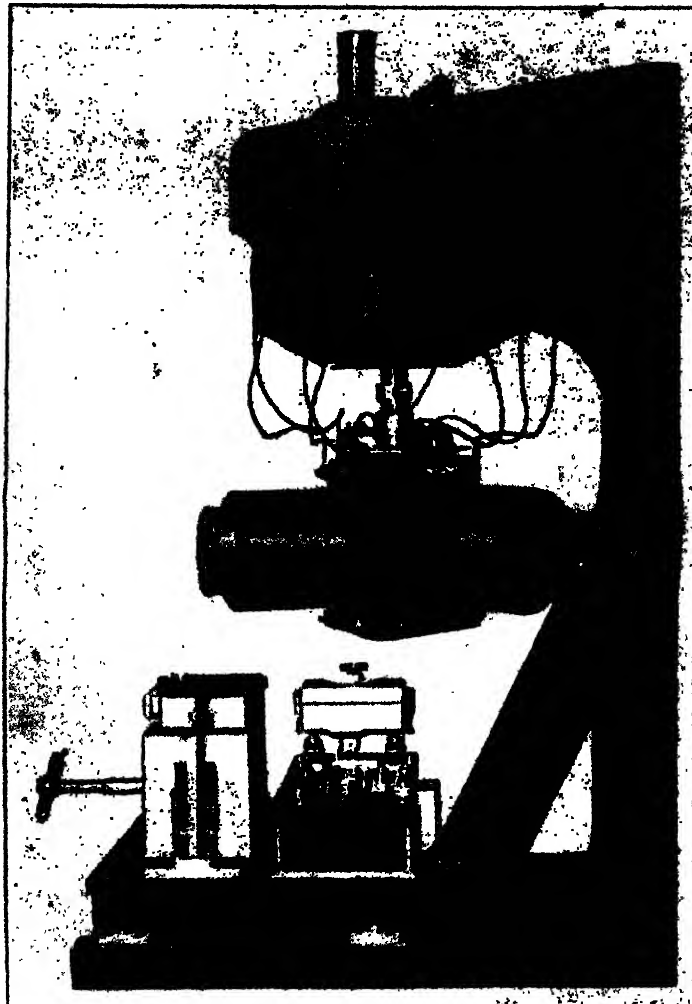
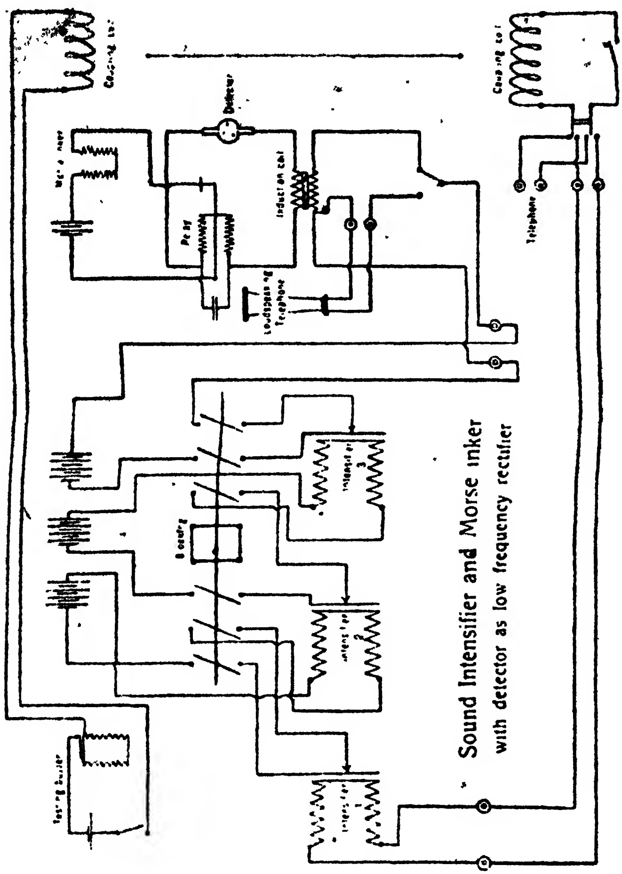


Fig. 149.

Telefunken sound intensifier.

ampères and the signals rendered so loud as to be audible at a considerable distance from the telephone.



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For ship working the intensifier is suspended in a well-sprung and damped cardan suspension, and it is

claimed that the apparatus requires little adjustment and remains constant for long periods. By the insertion of a small transformer and a rectifying detector it is also possible to work a Morse printer and thus obtain the advantage of a permanent record without sacrifice of distance. The diagram shows connections for reception either by printer or telephone.

CHAPTER IX

THE LEPEL SYSTEM

The Transmitter Musical Note Device—The Receiver—Modification for Receiving Undamped Waves

THE Lepel system, like the Telefunken, generates electrical oscillations by means of quenched sparks, but instead of a number of gaps in series only one is used and direct current instead of alternating. Fig. 151

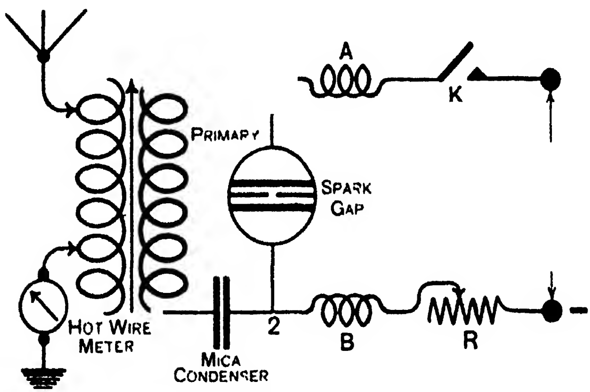


FIG. 151.

Lepel quenched spark transmitter.

shows diagrammatically the arrangement of sending circuits as used by the Lepel syndicate.

Across a 500 volt direct-current supply is joined the spark-gap, the positive electrode being made of pure electrolytic copper, and hollow to admit of water cooling: the negative electrode is made of delta metal and backs on to a water-cooled chamber. The electrodes are held apart by one or two paper discs (Fig.

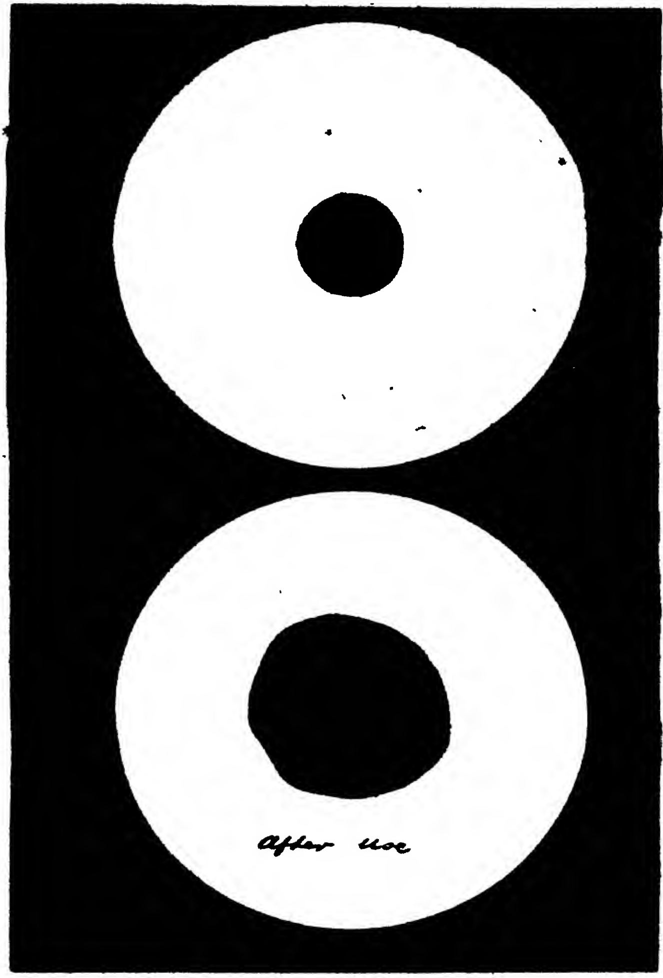


FIG. 152.

Paper discs used in Lepel transmitter.

152) having a circular hole punched out in the centre. By this method the spark-length is automatically set and the slow combustion of the paper allows a clean surface for the spark to pass, which greatly improves the regularity of the working. Across the spark-gap is shunted a circuit consisting of one or more turns of inductance which in the case of the Lepel system takes the form of a flat copper tape of large surface wound on a cylindrical former, and a condenser made from

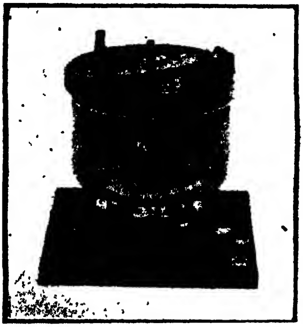


FIG. 153.
Lepel spark-gap.

copper foil with mica dielectric. The capacity of this condenser, it is found, should be kept rather large, something of the order of 100,000 centimetres being used. To the primary circuit is electro-magnetically coupled a secondary circuit, the ends of which are joined to antennae and earth respectively. A and B (Fig. 157) are choking coils. K is the Morse key and R is resistance built up of iron filaments enclosed in glass bulbs containing a hydrogen atmosphere. This form of resistance, which the reader will no doubt recognise as being similar to those used in the Nernst

lamp, constitutes a constant current device, and should the spark-gap from any cause become shorted the lamps at once increase their resistance and prevent the current from rising to dangerous proportions.

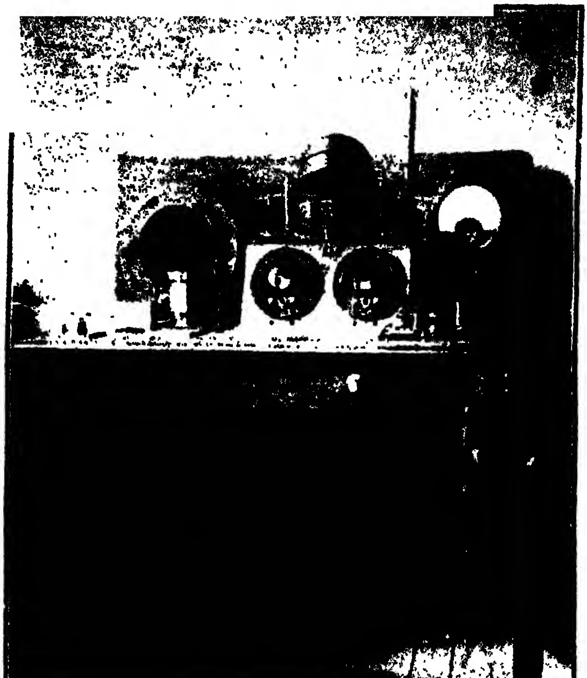


FIG. 154.
Complete Lepel installation.

The oscillations emitted from an arrangement of this kind are very feebly damped, the decrement being as low as .04, and are so nearly continuous that the effect on a receiver is that the signals are only audible as a faint blowing sound and probably could not be

detected at all at any great distance unless some form of interrupter was inserted in the receiver to cut up the current through the telephone. By an ingenious application of Mr. Wm. Duddell's discovery that a direct-current arc would, if shunted by a circuit containing capacity and inductance, emit a musical sound, the frequency of which corresponded to the electrical frequency of the circuit, the inventor has

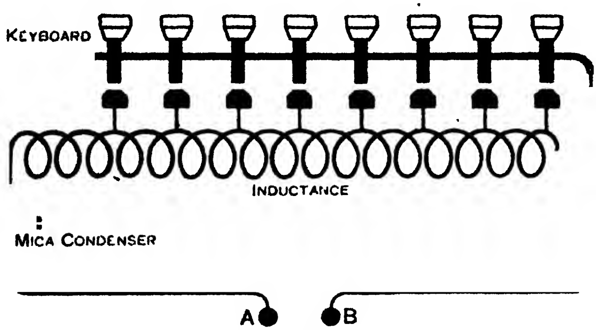
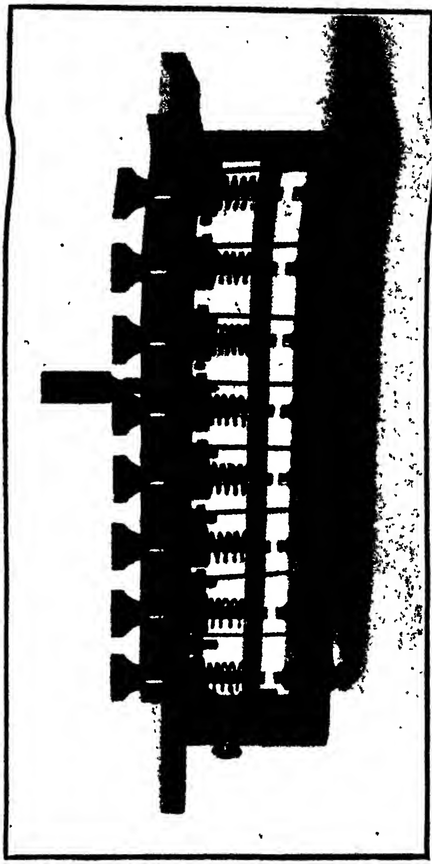


FIG. 155.

Musical note apparatus. Terminals A and B are connected to 1 and 2, Fig. 109. The coil is not coupled to either primary or secondary.

greatly extended the utility of the apparatus, inasmuch as by the use of the Duddell circuit the signals can be given out as pure musical notes and are thereby rendered distinctly audible in the receivers employed in ordinary spark installations. Each Lepel station is also fitted with a keyboard giving the operator a choice of eight notes so that it is possible to play simple tunes with the same ease as signals are sent. The receiver is of the three-coil type and is shown in Fig. 157. The primary coil is connected to the antennae and earth and has across its terminals a variable capacity by

means of which the tuning is effected. The inductance of the primary coil is also variable in several steps.



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Coupled to the primary is the secondary circuit, which consists of a coil variable in steps and a variable condenser. The tertiary circuit, which contains the

detector, is inductively coupled to the secondary. The detector is of the thermo-electric variety and consists of a graphite point resting against a piece of galena. The receiver can be arranged for the reception of signals from ordinary spark senders and from Lepel stations using musical notes, or for the reception of the undamped oscillations from a Poulsen transmitter,

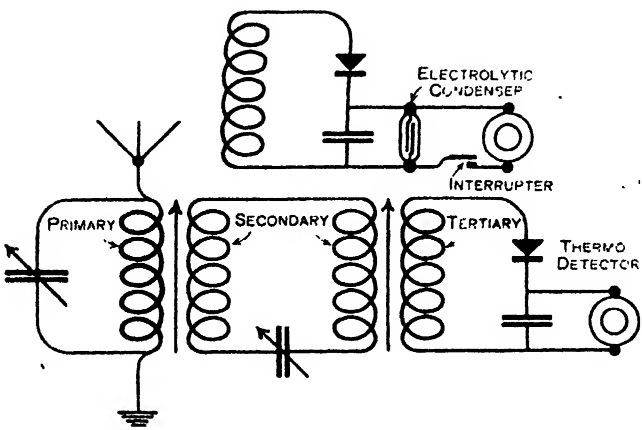

FIG. 157.

Lepel receiver. Arrangement of circuits for reception of spark signals. Inset shows modification to receive undamped waves.

or from a Lepel set working without musical-note device. The change is effected by simply moving to one side or the other a two-way switch; when it is desired to receive signals from a spark sender the switch is placed in a position such that the tertiary circuit is made up of the coil joined in series with a small blocking condenser and the detector; the phones being joined across the terminals of the condenser. When it is desired to receive the undamped waves

the switch is placed in the alternative position, when the circuit is composed as follows : In parallel with the blocking capacity is connected a piece of apparatus

FIG. 158.
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known as an electrolytic condenser. It consists of two pieces of foil about 3 centimetres in length by 1 in width immersed in an electrolyte and sealed into a glass tube, the wires by which connection is made to

the foil strips passing out through the walls of the tube. One lead of the telephone is also broken and a small intermittent contact, consisting of two gold wires crossing each other at right angles, inserted. The action of a receiver arranged in this way is as follows: on the oscillations passing across the graphite-galena junction it is heated and a small direct potential difference is created at its terminals. This potential difference acting on the electrolytic condenser polarises it—that is to say, a very thin film of hydrogen is

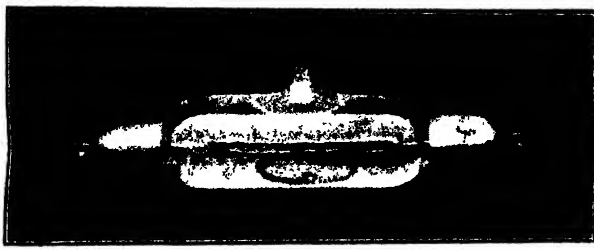


FIG. 159.
Electrolytic condenser.

deposited on the foil plates; this film constitutes the dielectric of the condenser and being microscopically thin the capacity is enormous, something of the order of two microfarads. After polarising it, and thereby making it a condenser, the thermo junction charges it, and this charge is sent through the telephone receiver every time the interrupter makes contact.

It will be seen that, like the Poulsen tikker arrangement, this is an integrating receiver—that is to say, the energy of the oscillations is collected over a given short period, determined by the speed at which the interrupter is running, and then discharged through the telephone, producing an enhanced effect.

CHAPTER X

GOLDSCHMIDT HIGH-FREQUENCY ALTERNATOR

A MACHINE which promises in the near future to revolutionise all existing methods of producing electrical oscillations is the Goldschmidt high - frequency alternator. For wireless telegraphy frequencies of from 40,000 upwards are needed and for communication over great distances large energy is also required. High frequency and large energy are contrary conditions and the frequency limit, depending as it does on the necessary cross-section of the winding, the insulation, width of pole-pieces and the safe circumferential speed of the rotor, is soon reached and is of the order of 15,000 cycles per second. The principle on which Dr. Goldschmidt's machine is based will be best understood in the following way: suppose the current from an alternator giving, say, 15,000 cycles per second be sent through the stator of a similar and synchronous running machine this would then deliver an alternating current at 30,000 cycles per second, this going into the stator of a third machine. An alternating current of 45,000 cycles per second would result, and so on. It is, however, unnecessary to employ a number of machines, the frequency transformation being effected by a single alternator. Suppose a machine constructed to give an alternating current of 15,000 cycles, stator and rotor being identically wound, has its stator excited by direct current (Fig. 160) the rotor will give an alternating current having a frequency of 15,000. The rotor is then short-circuited by means

of capacity and inductance, forming a closed oscillating circuit tuned to this frequency. By reaction between rotor and stator, an alternating current of 30,000 cycles is set up in the stator circuit (which is tuned to this frequency), namely, 15,000 by induction and 15,000 due to the revolution, this again reacts on the rotor to which is added a circuit tuned to a frequency of 45,000, and so on, the last circuit added containing the antennae and earth. *Fig.* 160 *shows such a machine* arranged to give a frequency in the antennae of 60,000,

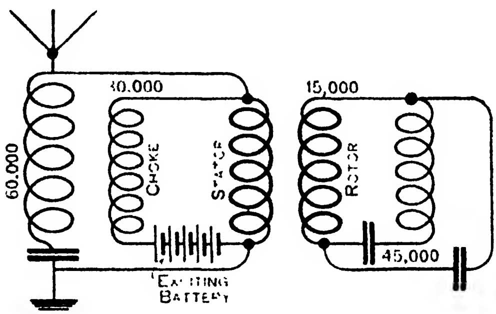


FIG. 160.

which equals a wave-length of 5,000 metres. It will be seen that the oscillations emitted by such a machine will be continuous and undamped and provided the machine runs at a constant speed there will be no fluctuation in the wave-length. It should be noted that the process is not a filtration of harmonics, as sometimes erroneously stated, but a true transformation of frequency, each frequency being only in existence on its own circuit. If the stator of the machine be excited by alternating instead of direct current the signals are heard in the receiver as a musical note.

with direct-current excitation it would of course be necessary to employ a receiver of the Poulsen tikker type. In the opinion of the company owning the Goldschmidt patents there will be no difficulty in constructing machines for any desired output, a machine having an output of 12½ kw. at a frequency of 30,000, which is the frequency corresponding to a wave-length of 10,000 metres, and an output of 8 to 10 kw. for a wave-length of 5,000 metres having already been constructed and operated successfully for a considerable time.

Fig. 161. Goldschmidt high-frequency alternator.

The highest frequency so far obtained is 100,000 cycles per second, which equals a wave-length of 3,000 metres. The efficiency of these machines is remarkably

high, at least for the long waves, the iron losses being kept low by minute subdivision of the cores. The efficiency of a machine giving a 10,000 metre wave is about 80 per cent.

For ship working, especially on small vessels where it is impossible to erect antennae of large size, it would be necessary to employ frequencies varying from about 1,500,000 to 450,000 to cover the wave-lengths used, and at these enormously high frequencies it is possible that the efficiency of the machine might be so low owing to iron losses that it would not be serviceable. For large stations where it is possible to erect large antennae it seems likely that the Goldschmidt high-frequency alternator or a machine similar to it will perhaps in the near future displace all other methods of generating electrical oscillations.

CHAPTER XI

PORTABLE INSTALLATIONS AND SMALL-POWER SETS

Marconi ½ kw. Set—Marconi Military Set—Marconi ½ kw. Set—Telefunken Small-Power Ship Set—Telefunken Simplified Receiver—Telefunken Airship Station—Lepel Military Set

In designing small-power sets and portable installations the chief considerations are light weight, compactness, the ease and speed with which the installation can be brought into operation, the limited amount of space available for their erection, simplicity of construction and manipulation, and in many cases the cost is an important consideration. The larger companies now manufacture sets designed for use in almost all circumstances and we have found it somewhat difficult to select examples. In the following pages will be found a description of the Marconi ½ kilowatt set, the Marconi cavalry set, small-power Telefunken ship's installation, simplified receiver for use on yachts and very small craft where a transmitter is unnecessary or impossible to install, also of the Telefunken airship installation and a short description of a Lepel military station.

Marconi ½ Kilowatt Set

This set is the result of much thought on the part of the Marconi Company's engineering staff to produce a small compact and efficient set suitable for cargo boats and other vessels where the ordinary standard ship equipments are too large.

The transmitter consists of rotary converter with starting switch, field regulating resistance and guard lamps, driven by the direct current from the ship's dynamo and supplying an alternating current to the alternating-current transformer. The Morse key, current-regulating device, ampère meter, fuses, and the primary winding of the transformer are connected in series and to the slip-rings of the alternating-current side of the converter. The secondary winding of the transformer is connected through two air-core choking coils to the condenser which forms the capacity in the primary oscillatory circuit.

The primary oscillation circuit consists of glass plate condenser and stud disc discharger and the primary coil of the oscillation transformer. The secondary winding of the oscillation transformer is connected on one side to the aerial through a variable tuning inductance and on the other side to the top plate of the earth spark-gap, the bottom plate of which is earthed.

The rotary converter is of the vertical type and occupies a minimum of floor space. It is designed to suit the direct-current supply available on the ship, has eight poles and runs at a speed of 2,250 revolutions per minute, thus giving a spark frequency of 300 per second. The discharger box is made of aluminium and is fitted on top of the converter. It contains an eight-stud disc, which is carried on the armature shaft by an insulating bush, the top of the box is made of ebonite, and carries two electrodes.

These electrodes are designed to be independently adjusted, and both electrodes can be moved so as to regulate the time of the discharge in relation to the alternator. A scale of 180° is fixed on top of the

Fig. 162.
Marconi ½ kw. set.

discharger box. The phase displacement is shown by an index mark on the disc carrying the electrodes. When the index mark is at 0° on the scale the discharge will take place at the moment the alternator gives maximum voltage; at 10° the discharge will take place 10° after the alternator has reached maximum voltage,

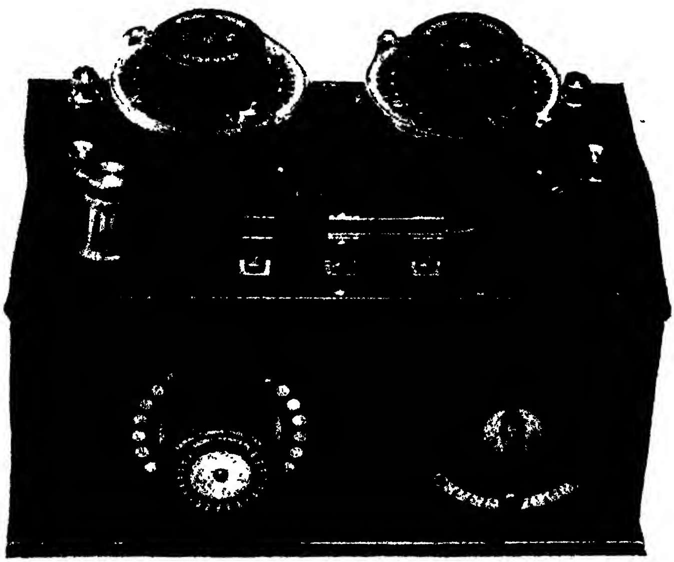


FIG. 163.
Marconi two-circuit tuner.

and so on. The primary of the oscillation transformer consists of about 7 turns of copper strip; connection to it is made by means of clips and a ready means is thus provided for wave-length adjustment. The secondary winding consists of about 20 turns of stranded copper wire wound on a wooden former 12 in. square. The coupling between the coils is varied by sliding

the secondary coil over the primary. The transmitting apparatus, with the exception of the oscillation transformer, Morse key, starting switch and field regulator, are enclosed in a sound-proof cabinet from which they can be withdrawn for inspection or repair by means of a sliding base on which they are mounted. The

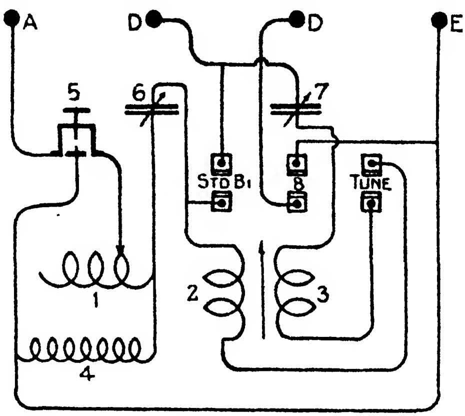


FIG. 164.

Circuits of tuner.

1. Aerial tuning inductance.
2. Primary coupling coil.
3. Detector coupling coil.
4. High self-inductance shunt.
5. Micro-meter gap.
6 and 7. Variable condensers.
8. Change-over switch.

tuner used is shown in Fig. 163. It has two circuits: the aerial circuit, the tuning of which is effected by means of a variable inductance and a variable condenser; and a detector circuit, which is tuned by means of a variable condenser. A change-over switch is provided for changing the detector from stand-by to tune position, and means are also provided for varying the coupling between the coils. It will

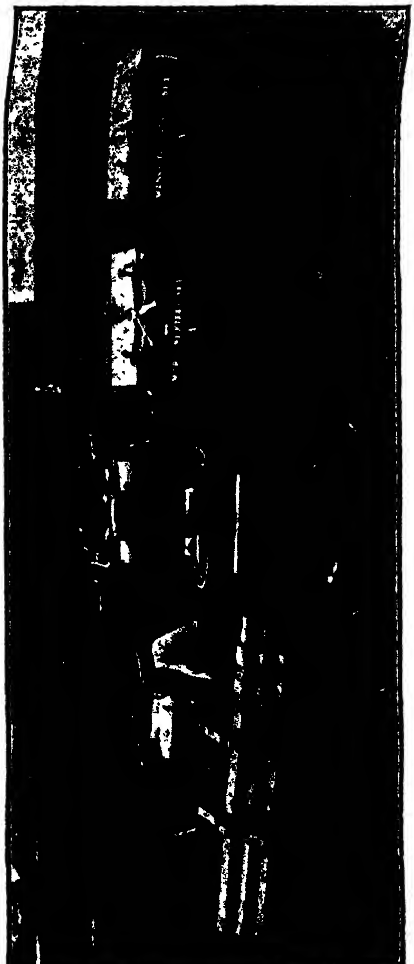


Photo *Topical*

FIG. 165.
Marconi field set packed for transport.

Photo Topical

FIG. 166.

Marconi field set ready for use.

be seen that this tuner is similar to the multiple tuner, the intermediate circuit being omitted. Although the

Photo FIG. 167. *Topical*
Marconi field set in use.

tuner is not so selective as the multiple tuner the omission of the intermediate circuit is no doubt fully compensated for by increased simplicity, which is of

the first importance in the circumstances which it has been designed to meet.

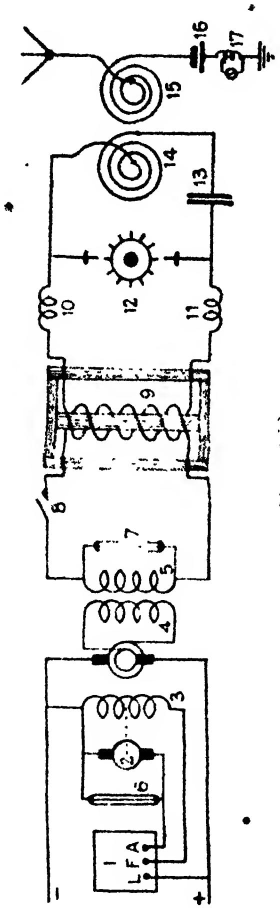


FIG. 168.

Circuits of 1 kilowatt transformer.

1. Motor starter and field regulator.
2. D.C. side of motor-generator.
3. Field winding of 2.
4. Rotor (field) of A.C. side of motor-generator.
5. Stator of A.C. side of motor-generator.

6 and 7. Guard lamps.

8. Morse-key.
9. Transformer.

10 and 11. Air-core chokes.

12. Rotary spark-gap.
13. Main condenser.
14. Primary of oscillation transformer.
15. Secondary of oscillation transformer.
16. Earth arrester.
17. Tuning lamp and choke.

The wave-length range is from 250 to 1,600 metres, and the detector used is the magnetic.

Marconi Portable Military Set

The photographs Figs. 165, 166 and 167 show a Marconi military set. In Fig. 165 the apparatus is seen packed for transport, Fig. 166 shows the station ready for use, and Fig. 167 the station in use. It will be seen that the complete installation, including mast, engine and dynamo, is carried on four saddles. The connections between the dynamo and transformer are made by means of a flexible cable and plugs, and the earth connection by means of the strip of wire-netting spread out on the ground, as shown in Fig. 167. The time required for the erection of one of these stations is very small, about twenty minutes being sufficient.

Marconi ½ Kilowatt Transmitter

Fig. 168 shows the circuits of the ½ kw. transmitter. The machine, it will be seen, is a motor generator (direct current to alternating current). The direct-current motor normally deriving its current from a battery of thirty secondary cells. The alternator, which is a twelve-pole machine, having a rotating field, gives an output of 250 watts at 110 volts. The armature makes 3,000 revolutions per minute, the alternating-current frequency is therefore 300 cycles per second. Fig. 169 shows the connection of the combined starting switch and field regulator, it will be seen that the resistance

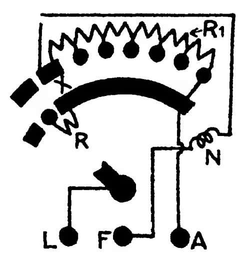


Fig. 169.
Combined starter and field regulator.

R. Starting resistance.
R_1. Field resistance.
N. No-volt release.
X. Normal position of starting handle.

in series with the armature winding is cut out in one step, and that if the handle is moved further to the right resistance will be inserted in the field and the speed of the armature increased. Normally the machine will run at the required speed without the insertion of any of the field resistance, but as the voltage of the battery falls, it may be necessary to add a little. Fig. 170 shows how the handle of the starting switch is maintained in contact with any desired stud. The low-tension, low-frequency circuit consists of the primary winding of the alternating-current transformer, connected in series with the Morse key and to the alternating-current terminals of the machine. It will be noticed that there is no reactance regulator in the circuit, this piece of apparatus being unnecessary as, when the machine is running at its normal speed, the alternating-current circuits are in resonance with the machine. The transformer, which is of the closed core type, steps up the alternating-current voltage to 5,700 volts. The high-tension, low-frequency circuit consists of the secondary winding of the alternating-current transformer, connected through the air-core chokes to the main condenser. The closed oscillatory circuit consists of the primary coil of the oscillation transformer connected in series with a rotary spark-gap and the condenser. The primary of the oscillation transformer is a flat spiral

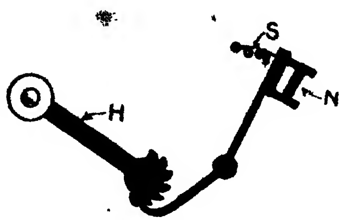


Fig. 170.
Showing mechanism of no volt release.

of copper tape, connection to it being made by means of clips. By altering the position of these clips the amount of inductance and, therefore, the wave-length of the circuit, can be altered. The condenser is of the tubular type, the plates being electrolytically deposited copper and the dielectric glass, six tubes are connected in parallel. The rotary gap is of the synchronous type, and is carried in the usual way on the shaft of the alternator. The open oscillatory circuit consists of a number of flat spiral inductances—which can be connected in series with each other by means of clips and flexible connecting leads—an earth arrester spark-gap, and tuning lamp and choke, all connected in series and to aerial and earth. The wave-length of the circuit is varied by including a greater or less number of the flat spiral inductances. A wave-length less than the natural wave-length of the aerial may be obtained by connecting in series with the aerial a condenser. The primary of the oscillation transformer is hinged, and the coupling can be varied by altering the angle between it and the flat spirals forming the inductance of the aerial circuit. On some ¼ kw. sets, an auto-transformer is used, the inductance in this case consisting of a cylindrical coil of copper tube, part of the coil being common to the open and closed circuits. The battery of condensers in this case is stood within the coil, the object being to economise space. If the ¼ kw. set is used as an emergency transmitter only, the apparatus with the exception cells, the charging switchboard, Morse key and the starting gear is mounted in a cabinet, the motor generator occupying the lower part and the oscillatory circuits the upper part. In cases where the set is the only

transmitter, a crystal receiver is provided, and the cabinet enlarged to receive it. The cabinet in this case is of the desk pattern, the upper portion of the front being hinged and when let down forming a writing table on which the Morse key is mounted. The receiving and starting and controlling gear are conveniently arranged in the upper part.

Telefunken Small-power Ship's Installation

Fig. 171 shows a small-power ship station capable of working over a distance of 100 miles or so. It will be seen that the whole of the apparatus is mounted in a cabinet and occupies very little space. The primary circuit is made up of the Morse key, variable resistance, and the primary of the induction coil joined in series across the supply mains. Across the secondary of the induction coil is the multiple spark-gap, consisting of six gaps between copper plates held apart by mica rings, and across this spark-gap is the primary oscillation circuit composed of Leyden jars and a portion of the flat spiral inductance. The aerial, with a variable inductance working on the variometer plan in series with it, is connected to one point of the primary inductance and the earth wire to another. As explained in the preceding chapter, the oscillations in the primary circuit are rapidly damped, and owing to the cooling of the gap there is no reflux back from the aerial circuit to the primary. Only one wave therefore exists, as after the primary has transferred its energy to the aerial the coupling between them is broken and the secondary or aerial circuit is left free to oscillate in its own natural period.

The efficiency is remarkably high, being about 50 per cent., and the damping of the oscillations emitted is

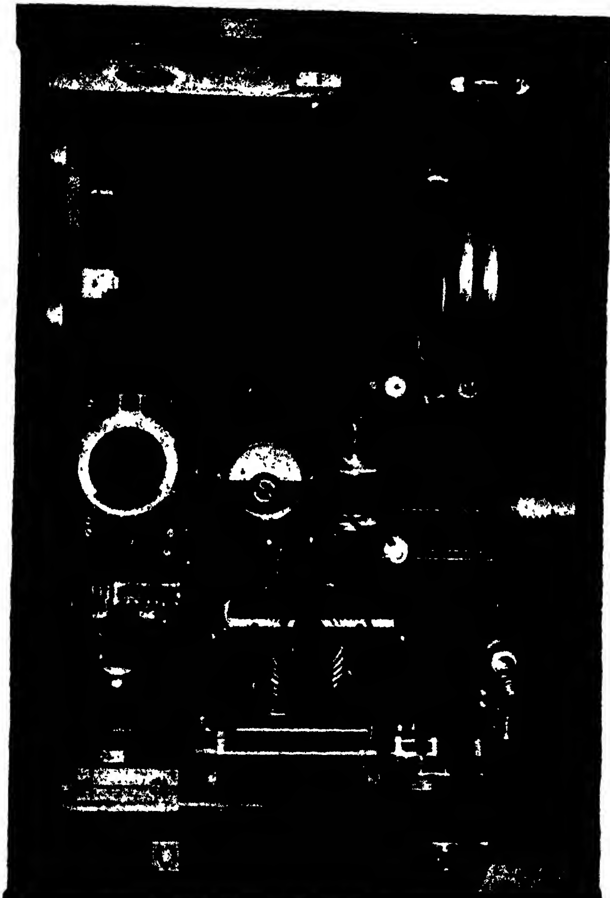


FIG. 171.
Telefunken small-power's ship installation.

very low. The receiver consists of a two-circuit inductively coupled tuner with thermo-electric detector.

The primary circuit is tuned by means of the variable capacity and by varying the inductance, the coil being variable in three steps. The secondary circuit contains the detector and owing to its resistance tuning is of little advantage.

Simplified Telefunken Receiver

This receiver has been designed to meet the demand for a receiving apparatus which would combine cheapness and simplicity in use with absolute reliability, even when used by persons who have received no special training in the use of wireless telegraph apparatus.

The conditions which such an apparatus must fulfil in order to meet the technical and practical requirements are as follows—

(1) The apparatus must be light in weight, of compact design, simple to operate, and cheap, both in original cost and in upkeep.

(2) The apparatus must have a wave-range which covers the wave-lengths used by lightships and coast signal stations (short waves, about 300 metres), the wave-lengths used on ship stations of the mercantile marine (medium waves, about 600 metres) and, finally, the wave-length used by high-power stations, such as Norddeich (long wave, about 2,000 metres).

(3) It must be possible to adjust the receiver to the above-mentioned waves even when it is used in connection with the smallest aerials found in practice—*e.g.*, on fishing vessels—and this adjustment must be carried out with a minimum loss of time and the smallest number of operations possible.

(4) A testing device must be
which it is possible for even

to assure himself at any moment that the receiver is in good working order.

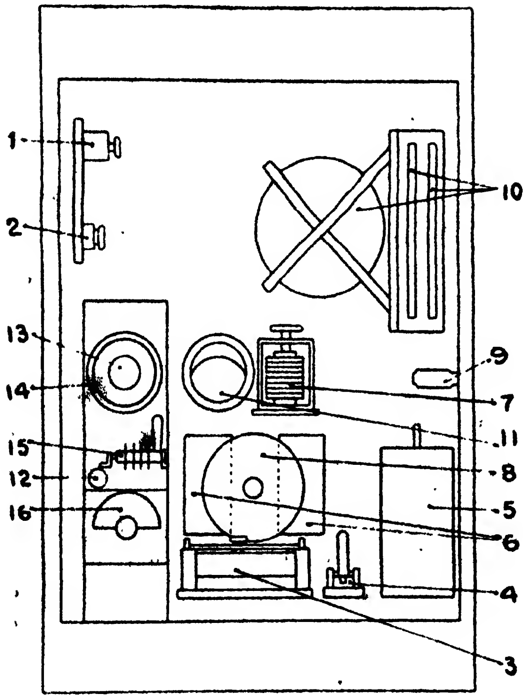


FIG. 172.
Key to Fig. 171.

1. D.C. switch.
2. D.C. fuse.
3. Variable resistance.
4. Morse key.
5. Induction coil.
9. Aerial lead insulators.
10. Aerial tuning coils.
11. Ammetre.
12. Detector.
13 and 14. Primary and secondary of [illegible]
15. Multiple switch.
16. Variable condenser.

lace all parts subject
asily.

The simplified receiver, type E 33, has been designed to meet this demand, and fulfils all the above-mentioned requirements. In its electrical qualities—*i.e.*, sensitiveness, adjustability, damping—it is all that an apparatus, intended mainly for practical use in the hands of untrained operators, can be required to be.

The aural receiver E 33 is suitable, firstly for fishing vessels, small coasting steamers, yachts, motor and sailing vessels on which it is not considered worth while going to the expense of installing and operating a complete transmitting and receiving station. In such cases it provides a complete substitute for an expensive chronometer for ascertaining the position of the ship and also provides the possibility of receiving weather reports and warning of approaching storms, thus greatly increasing the safety of navigation.

This apparatus is also adapted for use in signal and pilot stations and meteorological and scientific institutions where a reliable system of time control for the regulation of clocks is of importance.

On board balloons and small airships the receiver would probably be found of as much importance as at sea for the purpose of ascertaining position and of receiving weather reports.

(3) Changing switch (u) with positions marked in three colours corresponding to (2).

(4) Detector (i) with cartridge.

(4*a*) Spare cartridge for the detector (i_1).

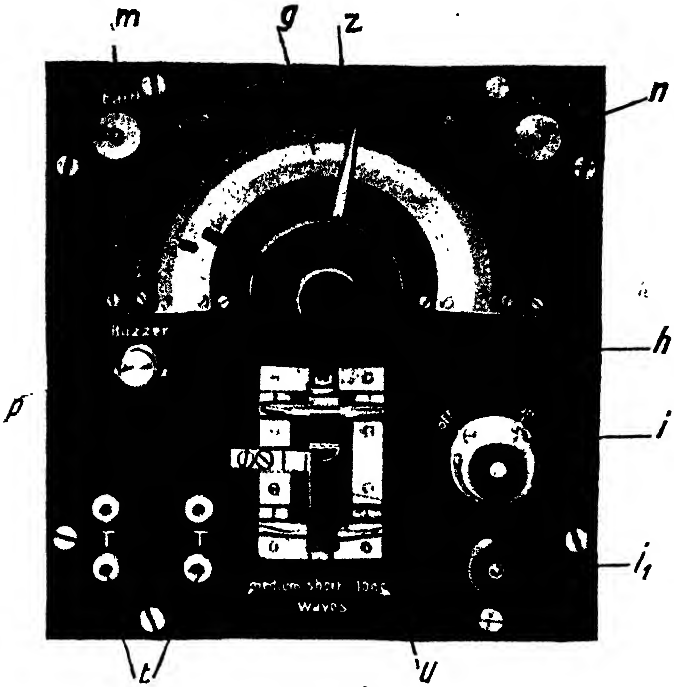


Fig. 173.

(5) Two telephone plug sockets (t).

(6) Rotating knob (p) for the testing device.

(7) Two terminals (n and m) for "aerial" and "earth."

Inside the wooden case are the various parts neces-

for adjusting the wave-length and for tuning,

such as variometer, condensers, buzzer, coils and dry wires and the connecting wires.

By moving the changing switch (u) and the pointer (z) to the positions marked by the three colours ("short," "medium" and "long" waves) the oscillatory circuit of the receiver, consisting of the rotating variometer and constant condenser inside the wooden case is tuned to the corresponding wave-length. A part of the energy collected in this oscillating circuit, which is connected with the antennae is transferred to the detector (i) by means of an aperiodic circuit tapped of the variometer. The detector converts the oscillations into an uni-directional current and they become audible as signals in the telephone, which forms part of the detector circuit.

It is advisable that the receiver and aerial should be erected by trained erectors as the aerial leads have to be arranged for each individual vessel to meet the special conditions of the case. The capacity of the antennae is dependent on the number, height and distance apart of the masts. The work of tuning up the apparatus to certain fixed wave-lengths, which are frequently used—*e.g.*, 300, 600 and 2,000 metres—should be carried out by skilled erectors at the time of the erection, and the exact positions for these wave-lengths marked on the coloured plates below the scale of degrees.

The exact position of these marks will depend on the capacity of the aerial. When using the apparatus, if the wave-length of the signals to be received is known, the pointer is set to the position corresponding to the wave-length required. It should, however, be noted that the external influences, weather, etc., frequently

render it necessary to adjust the pointer a few degrees above or below the normal position in order to attain the maximum intensity of the signals in the telephone.

In order to test the correct adjustment of the ap-

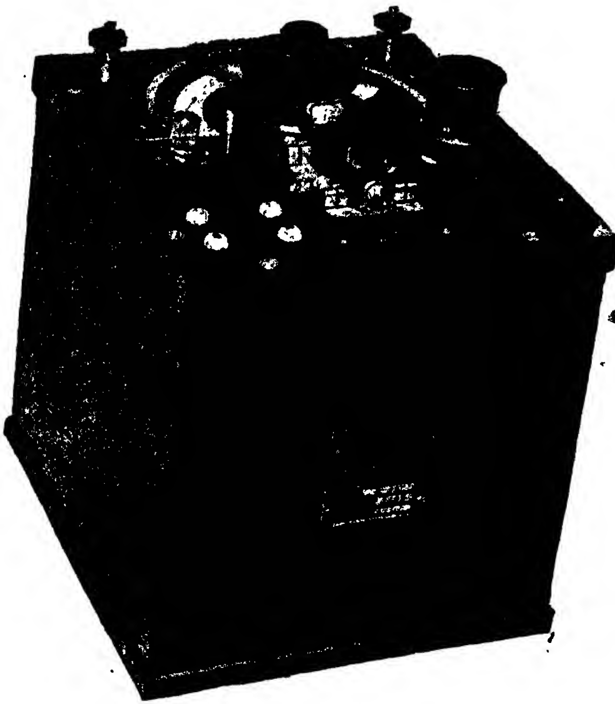


FIG. 174.
Simplified Telefunken receiver.

paratus, and to ensure that antennae, connections, detector and telephone are in good order before beginning to receive signals, the knob (p) of the testing device, which is on the left-hand side of the plate, should be turned momentarily in the direction of the

arrow. If the apparatus is in order, a buzzing sound will then be heard in the telephone. If this sound is not heard, or if it is very weak, the knob (r) of the detector (i) should be carefully turned until the buzzing is heard properly. As a rule nothing further is required to render the receiver ready for working.

Should the detector become injured by severe atmospheric discharges, the spare detector cartridge, which is supplied with every apparatus, should be inserted in place of the damaged one. This is a very simple matter, and is effected with very few operations.

Telefunken Airship Station

In designing radio-telegraphic apparatus for airships and aeroplanes due consideration has to be given to the extremely limited space available on such craft, and the main points aimed at are small weight and dimensions.

In addition to the airship station which is described below in detail the Telefunken Company also build stations for aeroplanes. The total weight of these stations has been reduced to about 55 lb. Experiments are now being carried on with these apparatus, and will enable a definite design to be decided upon very shortly. The apparatus of which the airship station consists are mounted in a wooden cabinet, which is divided by means of a vertical partition into an open front section and a closed back section.

In the front open half are all the separate parts of the transmitter and receiver which have to be operated or adjusted by hand, while the back closed half of the cabinet contains all those parts of the transmitter

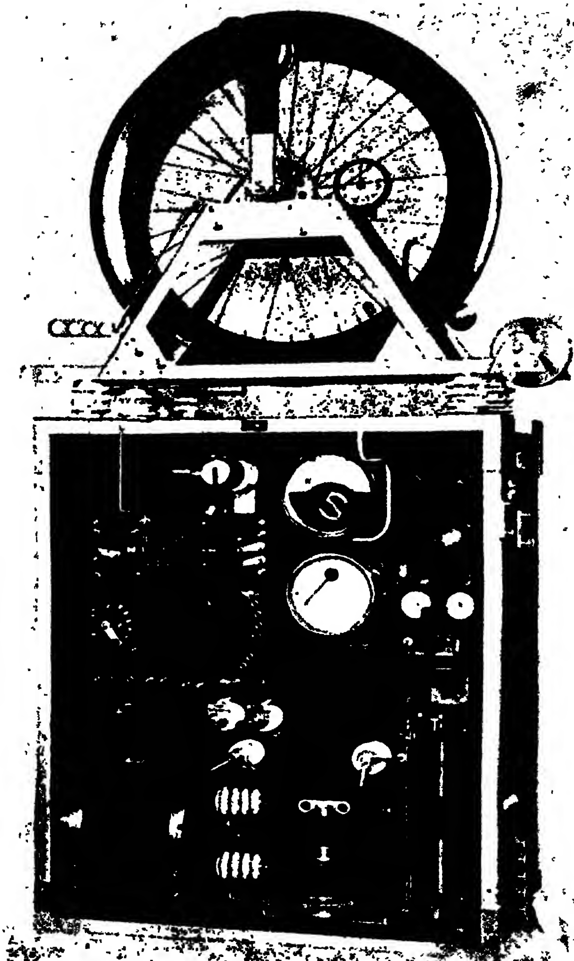


Fig. 175.

Telefunken airship installation.

which need no attention, such as the self induction and capacity.

A small winch is mounted on four porcelain insulators on the top of the cabinet. On this winch a phosphor-bronze aerial wire about 200 metres long is wound. The crank, pawl, brake, counter and drum of the winch are heavily insulated. Outside the cabinet on the right-hand side are the terminals for the connections from the source of power and for lighting the station. The external dimensions of the cabinet are: width about 600 cm., depth about 330 cm., and height about 760 cm., and the station requires a vertical space of about 1,350 cm.

The bronze wire of about 3 mm. diameter wound on the winch serves as an aerial and can be wound off by means of the insulated hand crank to suit the wave-length chosen. The wire passes over insulated pulleys over the edge of the car, and hangs down freely. A counter shows the number of metres wound off.

An aerial change-over switch, in the cabinet, is arranged so that when in the transmitting position it interrupts the receiver circuits and when in the receiving position interrupts the main power circuit so that the sensitive receiving apparatus are not likely to be damaged by an accidental pressing of the key while receiving. The metal frame of the car, etc., forms the counterpoise.

The source of power is an alternating-current generator with direct coupled exciting machines. The output of the generator at about 3,000 revolutions per minute is about 500 watts, and the frequency is 500 per second. The generator is driven from the motor of the airship either by means of a belt or chain or by

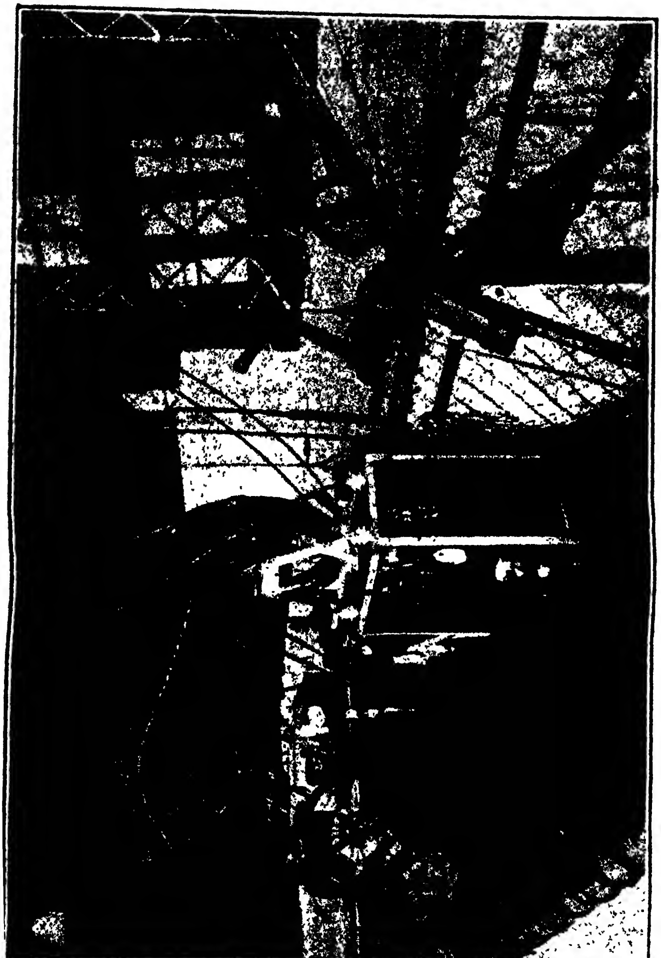


FIG. 176.
.efunken airship

means of an intermediate gearing with a throw-out clutch.

A voltmeter and a pressure speed regulator and the fuses are mounted in the cabinet.

The transmitter consists of the following: transformer, quenched spark-gap, excitation capacity and self-induction, aerial lengthening coil, ammeter, Morse key and a changing device for three different wave-lengths. The capacity self-induction and lengthening coil are in the back closed half of the cabinet, the other parts are conveniently arranged in the front half of the cabinet so as to be easily accessible.

The excitation circuit of the transmitter can be tuned to several waves, ranging from 300 metres to 600 meters. For the different wave-lengths corresponding aerial coils, fitted with connecting plugs for specified wave-lengths, are connected in the aerial. The exact tuning is effected by winding off more or less of the antennae wire. The antennae wire is marked in different colours corresponding to the connections on the excitation and coupling coils.

If an airship is flying very low down only the short wave-lengths can be used.

The receiver is a complete aural receiver of a special type designed for airships. The separate parts of the receiver are as follows: variable self-induction detector, telephone, blocking condenser, and a blocking switch for the detector. Two plug sockets are provided for the telephone. All these parts are mounted in the cabinet.

The whole of the self-induction which is used for increasing the natural wave-length of the aerial is also used for direct coupling the detector. The

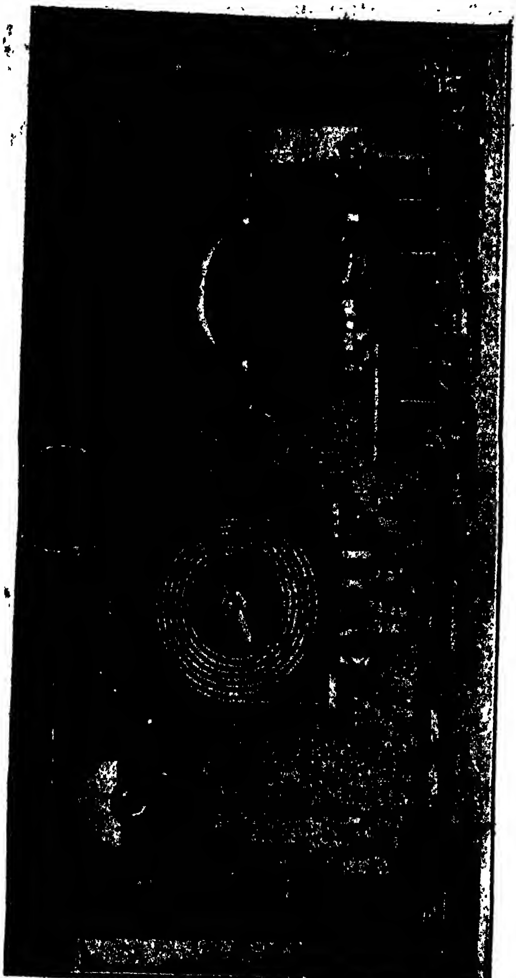


Fig. 177.
Portable Lepel ins

detector coupling turns can be varied by means of plugs. The number of turns for lengthening the aerial remains approximately constant for all wave-lengths, so that only the detector coupling turns need to be regulated.

The effective range of the station communicating with a wheeled military station is about 100 to 200 kilometres.

The weight of the complete station is as follows—

Apparatus cabinet and winch, about . .	155 lbs.
Alternator and exciting dynamo, about . .	120 ,,
Total weight, about	275 lbs.

Lepel Portable Station

Fig. 177 shows a Lepel military set arranged for waggon transport. The flat spiral coil to the left of the photograph is the primary inductance which is varied by turning the handle. The quenched spark-gap is immediately in front of it. On the table to the left of the spark-gap is the small mica condenser which forms the primary capacity, and to the left of this are the two choke coils. The secondary coil is a flat spiral mounted on a leaf hinged at the bottom and the coupling is varied by means of the strap seen above the primary coil. The tuner is of the three-circuit type and is seen to the right of the photograph together with the variable condenser, detector and blocking switch. The mast used in conjunction with this set is of the telescopic variety, made of steel tube and has a height of about 90 ft. when fully extended.

CHAPTER XII

MEASUREMENTS

Capacity—Dielectric Losses in Condensers—Capacity of Aerial—Insulation Resistance of Aerial—H.F. Resistance—H.F. Currents—Wave Meters—Measurement of Wave-Length—Resonance Curves and Damping Decrements—The Marconi Decremeter—Logarithmic Chart—Inductance—Coefficient of Coupling—Calibration of Receiving Circuits—Earth Plate Resistance—Strength of Received Signals—Energy in Aerial

THE capacity of a condenser varies directly as the area of the opposing surfaces and inversely as the thickness of the dielectric or distance between the plates. The nature of the dielectric also has considerable influence in determining the capacity of a condenser. Supposing, for instance, that two plates, each having an area of 1,000 square centimetres and the distance between the plates being ·1 of a centimetre, its capacity K can be calculated from the formula * $K = \frac{S}{4\pi t} k$ (where S is the area of one of the plates in square centimetres, $\pi = 3{\cdot}1416$, t = thickness of dielectric and k = the dielectric constant which in the case of air is taken to be unity), and will be found to be 795 centimetres.

* The formula for capacity given above is based on the assumption that the lines of force between the plates are straight lines; it must only therefore be used when the thickness of dielectric is very small compared with the surface of the plates.

If now the space between the plates be filled with mica, the capacity will be greatly increased and in fact will be about five times as great as when the dielectric was air. This is due to the fact that various materials allow electro-static induction to take place across them in varying degree. Thus mica permits it to take place about five times as well as air.

The ratio that exists between the capacity of two condensers of equal size, one having air for a dielectric and the other some other material, is termed the dielectric constant for that material and is denoted by the letter *k*. At the end of this chapter will be found a table of dielectric constants of the more usual materials used in condenser making, but it should be noted that different specimens of the same material often exhibit marked differences in the value of their dielectric constants, and that therefore the formula given above should only be used to calculate the value of an air condenser. If, however, we possess a standard condenser it is a simple matter to ascertain the value of an unknown capacity. Referring to Fig. 178, K is the known capacity; K_1 is the capacity to be measured. R and R_1 are variable resistances,* which

* These resistances, as is perhaps well known to our readers, are built up of a wire doubled back on itself to form a non-inductive winding. In the case of the higher resistances it is necessary to use a considerable length of wire, which results in the coil having considerable capacity, and when used with a quickly pulsating current the coil would behave exactly as a condenser; to obviate this, the coil should be built up of a large number of smaller non-inductive resistances joined in series. When this is done it will be seen that the capacity is reduced to a minimum, as we are in effect joining a number of capacities in series.

must, however, be non-inductive and of small capacity, and T is a telephone receiver. To the points A and B an intermittent voltage is applied, which may conveniently be done by joining in series a dry cell and quick-running interrupter and connecting them across the points.

On adjusting the resistance a point will be found at which the sound in the telephone will disappear or at least be a minimum. When this point is found a

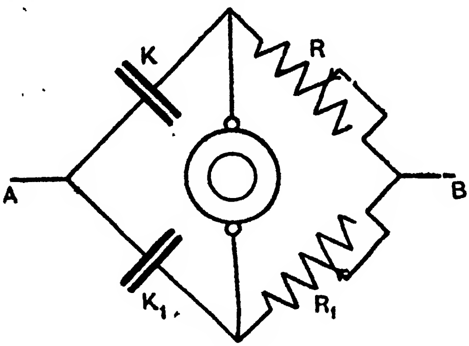


FIG. 178.

certain ratio exists between the condensers and the resistances such that $K : K_1 :: R_1 : R$—that is to say, as K is to K_1, so is R_1 to R, and the value of the resistances in ohms being known and also the value of the standard condenser it is a quite easy matter to find the value of the unknown capacity. This method is known as the De Sauty bridge method, and is suitable for the measurement of capacities from a few hundred centimetres upwards provided that the capacity to be measured and the standard condenser do not differ by more than a small multiple. When the unknown capacity has a dielectric of different material to the

standard it will sometimes be found impossible to obtain a complete cessation of sound in the phone owing to unequal absorption of the dielectrics, but in

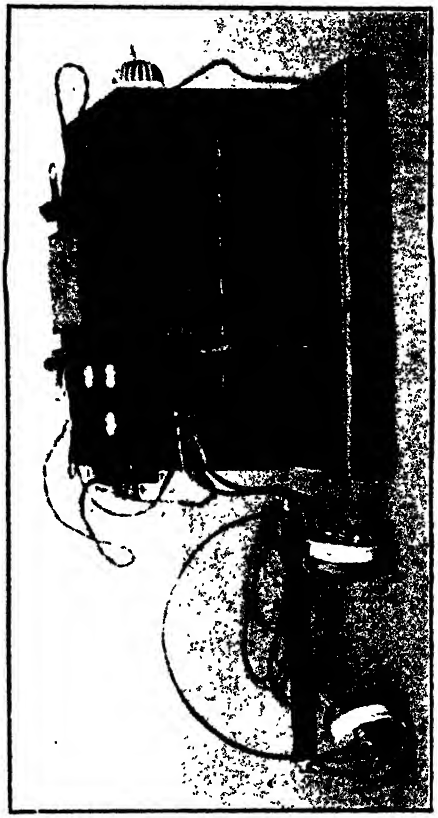


Fig. 179.

Practical form of De Sauty bridge for capacity measurement.

such cases the method can be depended upon to give results accurate to within a few per cent. Fig. 179 shows a convenient and practical form of the apparatus

devised by the writer; in the box are three standard condensers whose values are 60,000, 10,000 and 1,666 centimetres respectively. The box also contains a quick-running buzzer which supplies the intermittent voltage necessary. The resistance is a standard resistance box reading to 1,100 ohms in steps of 1: the condenser to be measured is inserted in the clips

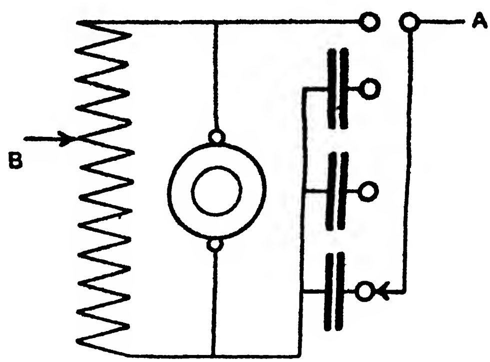


FIG. 180.

Connections of De Sauty bridge shown in Fig. 179.

on top of the box. Fig. 180 is a diagram of the connections. Another method suitable for the measurement of a small condenser is to join it in series with an inductance of known value and by means of a small Rhumkorff coil to cause the circuit so formed to oscillate, then by means of the wave meter the wavelength is ascertained and the value of the capacity in microfarads found from the formula—$\lambda = 59{\cdot}6\sqrt{CL}$, where λ = wave-lengths in metres, C = capacity in microfarads and L = inductance in centimetres.

Dielectric Constants

Substance.	*Dielectric Constant*
Sulphur	2·24
Ebonite	2·0
India-rubber	2·12
Gutta-percha	2·46
Paraffin	1·98
Shellac	2·95
Mica	6·0
Castor oil	4·78
Turpentine	2·15
Petroleum	2·07
Glass (according to quality)	6·6 to 9·8

A convenient standard inductance can be made *by winding 8 turns of double silk-covered wire gauge* number 18 on a cylindrical former 20 centimetres in diameter: this will have an inductance of 25,000 centimetres.

Dielectric Losses in Condensers

We have already seen that the losses in an oscillating circuit are caused, first, by the resistance of the conductor forming the inductance and in the case of a circuit used to generate electrical oscillations by the resistance of the spark. The condenser unless it have air as dielectric will also dissipate energy, and it is therefore necessary to be able to measure this energy loss caused by the dielectric and thus judge of its suitability for the purpose. If we are in possession of a variable air condenser the capacity of which is great enough to cover the capacity of the condenser whose energy-absorbing powers we wish to ascertain, the matter is comparatively simple and should be carried out as follows—

The condenser under test is joined up with an inductance so as to form an oscillating circuit. Included in

the circuit is a calibrated hot wire milliampere meter. A second circuit, consisting of capacity, inductance (either or both of which are variable) and a spark-gap, and excited by means of an induction coil, is then set up and loosely coupled to it. The exciting circuit is then tuned by varying its capacity or inductance until the small hot wire ammeter in the first circuit gives its maximum reading. This will indicate that the two circuits are in resonance. The current in the circuit as shown by the meter is then noted. The coupling between the circuits should be *kept constant* and the variable air condenser substituted *for the* condenser under test and its capacity varied till the meter again gives its maximum reading and indicates the attainment of resonance. Now obtain a variable non-inductive resistance and join it in circuit with the condenser and inductance and vary its resistance until the meter shows the same reading as it did when the condenser to be tested was in circuit. It will be quite evident to the reader that the energy absorbed by the dielectric of the condenser under test is equal to the energy-absorption of the resistance which we have included in circuit with the air condenser which has been substituted for it, and can be found by the aid of the formula C^2R, where C^2 is the mean square value of the current and R is the equivalent resistance. Fig. 181 shows a convenient method of connecting up the circuit to make the test. A is a switch which in one position connects in circuit the condenser to be tested and in the second position the variable air condenser and non-inductive resistance.

The chief difficulty in carrying out this test arises from the fact that the spark in the exciting circuit is

sometimes difficult to maintain constant. Care must also be taken to prevent any brushing from the edges of the air condenser plates, as if this takes place the energy absorption may be considerable. A useful comparative test in certain circumstances can be made in the following way: Connect the condenser under test in circuit, instead of the usual condenser on the

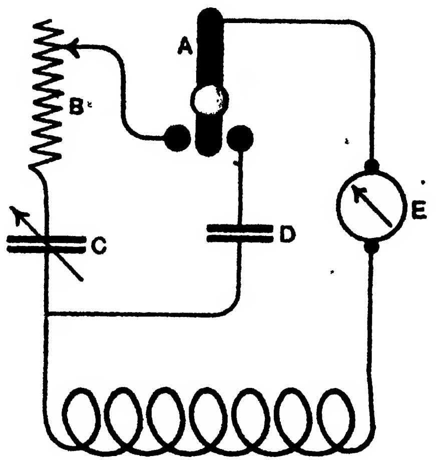


FIG. 181.
A=Switch. B=Non-inductive resistance. C=Variable air condenser. D=Condenser to be tested. E=Hot wire meter.

receiver, bring the circuit to resonance with a station sending out signals and measure the strength of the incoming oscillations, as per instructions given in a later part of this chapter. Now insert a variable air condenser in its place and measure strength of incoming oscillations; we can now form an idea as to the energy-absorbing power of the dielectric by its effect in reducing the strength of the signals.

Capacity of Aerial

Except in very simple cases, such as that of a single vertical wire, it is not possible to calculate with any accuracy the capacity of an aerial. The capacity of a single vertical wire can be calculated from the formula $C = \dfrac{l}{2\log_\varepsilon \dfrac{2l}{d}}$, when $C =$ Cap. in centimetres, $l =$ length of wire also in cm., $d =$ its diameter: as an example suppose the antennae to consist of a single vertical wire of length 50 metres and diameter 3 millimetres, C will equal 5,000 and d will equal ·3,

$$\therefore\ C = \frac{5000}{2\log_\varepsilon \dfrac{10000}{\cdot 3}} = \frac{5000}{20{\cdot}8} = 240 \text{ cm. approx.}$$

The addition of wires in parallel will not, however, increase the capacity in direct proportion to the number of wires, owing to the fact that the wires exercise a screening effect on one another which renders the distribution of the lines of force unsymmetrical for each wire. *The capacity may be said to increase* roughly as the square root of the number of wires in parallel—thus four wires would give double the capacity of one wire, nine wires three times the capacity, and so on. Assuming the possession of a wave meter and a variable condenser the capacity of which is known it is quite a simple matter to measure the capacity of the aerial: the procedure is as follows: first add a coil of wire of a few turns to the aerial and excite by means of a small spark coil; then by means of the wave meter measure the wave-length; having done this set the wave meter to double the

wave-length and then by means of the switch (Fig. 182) join the variable condenser across the aerial coil, adjust till it is in resonance with the wave meter, the capacity of the aerial will then be equal to one-third of the added capacity. As an example, supposing that the wave-length of the aerial with the coil in series was 100 metres and that the amount of capacity necessary to bring the wave-length up to 200 metres was 600 cm., the capacity of the aerial would be 200 cm.

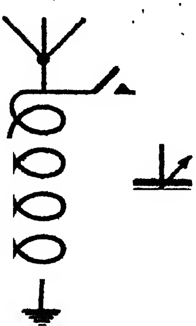


FIG. 182.

INSULATION RESISTANCE OF AERIAL

It is of the utmost importance that the aerial should possess a high-insulation resistance, the measurement of which is made as follows: disconnect the aerial from the circuit and connect it to one terminal of a very sensitive galvanometer which has previously been calibrated; the second terminal of the galvanometer is connected to one pole of a direct-current dynamo or battery of cells giving a voltage of from 200 to 500 volts; the other pole of the dynamo is connected to the earth plate. Observe the current indicated by the galvanometer and the insulation resistance of the aerial can then by the aid of Ohm's law be found. Thus, supposing the voltage of the dynamo to be 500 volts and the current indicated by the galvanometer 2 micro-ampères, the insulation resistance will be found to be 250 megohms or 250,000,000 ohms. The insulation resistance will be found to vary greatly with the

atmospheric conditions prevailing, thus it is much higher in fine, dry weather than when the atmosphere is saturated with moisture.

It should be noted that although the aerial may have a very high insulation resistance it is not necessarily well insulated for oscillatory currents, or for the very high potentials used in Radio-Telegraphy. To secure perfect insulation we must arrange that the aerial does not run close to any earthed metal-work, and more especially that it does not run parallel to it. If this is not done, oscillations will be set up in the earthed metal-work by induction from the aerial and energy absorbed as effectually as if they were in actual metallic contact. It is for this reason that the guys supporting the mast of a Radio-Telegraph station are cut up into short lengths by means of insulators.

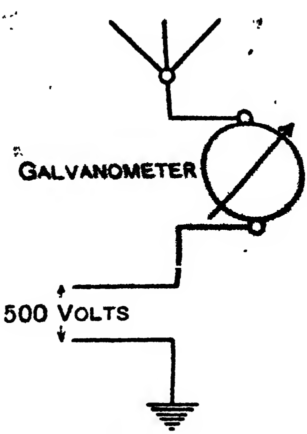


FIG. 183.

HIGH-FREQUENCY RESISTANCE

By Ohm's law the resistance of a conductor will vary as its length and inversely as its cross-sectional area, but this only applies to conductors carrying steady currents. The high-frequency resistance of a conductor is often very different from its resistance to steady or slowly alternating currents. The difference in the resistance will depend on the frequency of the

alternations of current and upon the size or cross-section of the wire. A wire of large gauge will have a resistance many times higher for high-frequency currents than for a direct current; this is due to the concentration of the current on the outer skin and therefore to the reduction of the effective cross-section of the wire. If the wire were of a small gauge, say No. 38, the difference in value of the resistance for high and low frequencies would be very small, practically nil. For this reason many of the coils used in Radio-Telegraphy are made from laminated conductors—that is to say, a conductor built up of several hundred very small insulated wires. For the same reason they sometimes are made from tubes instead of solid wires. There is no convenient way for the operator to measure directly the high-frequency resistance, but if the coils are constructed as above, they can be measured in the ordinary way on the Wheatstone bridge and the high-frequency value will differ only very slightly from the value so obtained.

High-Frequency Currents, Measurement of

For the measurement of high-frequency currents the ordinary hot wire ammeter is of no use, for the reason that it is constructed on the shunt principle—that is to say, the greater portion of the current to be measured is diverted through the shunt, which is a stout copper wire or strip, and only a small known fraction passes through the wire of the meter. As explained in the chapter on high-frequency resistance, a thick wire has a much higher resistance to high-frequency currents than to steady or low-frequency currents, and therefore as the shunt consists

of a stout wire its resistance would vary with the frequency of the current to be measured and it would thus be impossible to use such an instrument. A piece of apparatus known as a Reiss thermometer is, however, a suitable device with which to measure a high-frequency current. It consists of a bunch of fine bare wires connected between terminals and enclosed in a glass bulb; *in connection with the bulb is a U-shaped* stem containing a liquid coloured to make it easily visible. If now a direct current be passed through the bunch of fine wires they will be heated and in turn heat the air in the bulb, which will expand and drive the liquid up the tube. By passing various currents through the wires and noting the height to which the liquid rises in the tube for each current the instrument can be calibrated in ampères. The heater, being formed of a number of fine wires in parallel, will have the same resistance to high and low-frequency currents and is therefore suitable for the measurement of a high-frequency current.

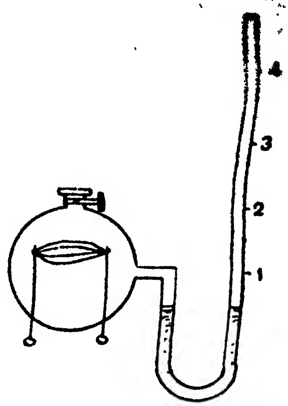


FIG. 184.
Reiss thermometer.

Fig. 184 shows a Reiss thermometer. If such an instrument is not available the high-frequency current can be roughly measured by inserting in the circuit a piece of fine wire and noting how many strands in parallel the current will melt. Having ascertained the

number, take the same number and pass through them a direct current, increasing it till they melt and noting on the ampère meter, which should be joined in the circuit with them, the current at which they melt. This current will be equal to the high-frequency current the value of which it is desired to know.

Wave Meters

This important piece of apparatus consists essentially of an inductance and a capacity, either or both of which are variable, the frequencies or wave-lengths corresponding thereto for the various positions of the pointer on the condenser scale, or, if the inductance is variable, on the scale of the inductance, having been predetermined and either plotted as a curve or arranged in table form. In the commercial form it is usual to have a fixed inductance or perhaps one variable in two or three steps and a condenser whose capacity is continuously variable between limits determined by its dimensions and the nature of its dielectric. Means must also be provided to make evident the attainment of resonance. The Marconi Company manufactures a very convenient and portable form of wave meter (Fig. 185). It consists of a coil of wire wound on a rectangular wooden frame and mounted in the lid of the carrying case, the ends of the coil are connected to the terminals of a variable condenser, and across the same terminals are shunted a telephone receiver and carborundum crystal; the connections are shown diagrammatically in Fig. 186, where A is the coil, B the condenser, C the carborundum crystal and T the telephone. To measure the wave-length of any given transmitter the key is closed and the phones of the

wave meter being placed on the head of the observer the condenser is adjusted until the sound is at a maximum; the wave-length is then read from the table in the lid of the box, which gives the wave-lengths corresponding to every degree of the condenser scale. Such

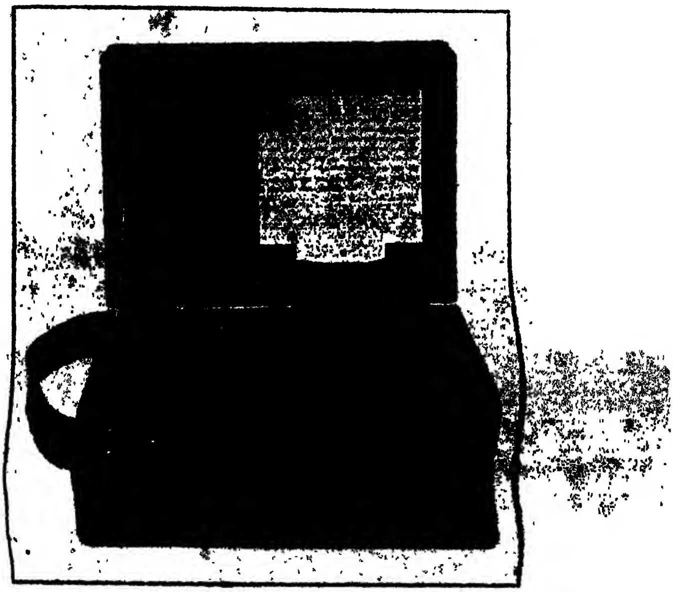


FIG. 185.

Marconi wave meter.

an instrument as the above, although very convenient for the determination of wave-lengths, cannot be used for the measurement of the damping of the oscillations, as it is not possible for the ear to estimate the relative value of different currents which is necessary to the finding of the decrement of the oscillations.

A different pattern of wave meter must therefore be used. Fig. 187 shows an instrument suitable for the plotting of resonance curves and for the measurement of decrements. It consists of the usual coil and variable capacity, but in place of the telephone and carborundum crystal is a small hot wire meter. This meter, however, is not put across the condenser, but in series with it and the coil (Fig. 188). The scale is calibrated by means of a direct current and therefore shows the R.M.S. value of the oscillations; by squaring the readings on the scale, the mean square value can be obtained. Provision is also made for the insertion of a small resistance by means of which the damping of the wave meter itself can be eliminated, but as this is small it can as a rule be neglected.

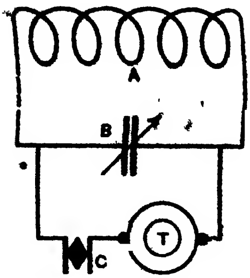


FIG. 186.
Connections of Marconi wave meter.

The frequency of the oscillations can be found from the formula $n = \dfrac{5{\cdot}033 \times 10^6}{\sqrt{CL}}$, when n equals the frequency C the capacity in microfarads and L the inductance in centimetres. The appended curves show frequency and oscillation constant for wave-lengths up to 2,000 metres.

Resonance Curves and Damping Decrements

To plot a resonance curve the wave meter should be set up in proximity to the transmitter and the condenser adjusted till resonance is obtained, which will

be indicated by the hot wire meter *giving its maximum* reading. The coil of the wave meter must be placed

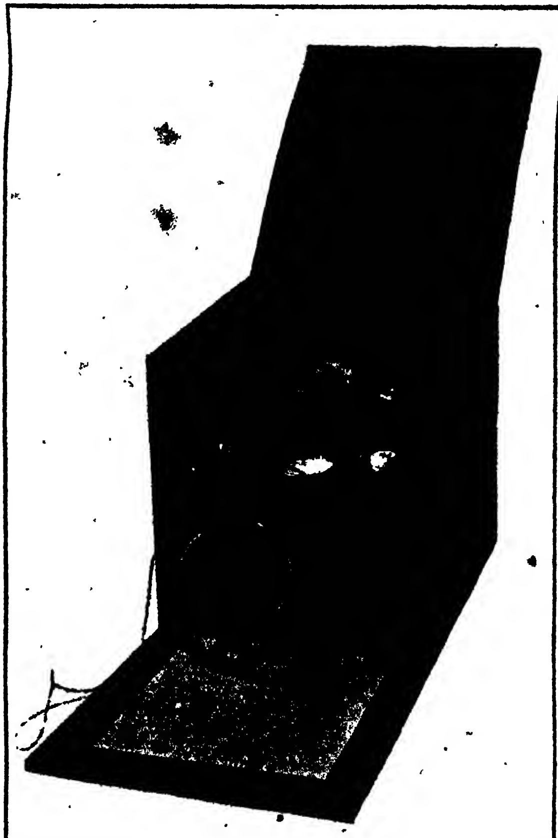


FIG. 187.
Wave meter.

in such a position that the reading on the meter comes just within the scale, say three parts over. The

resonance wave-length and the mean square value of the current at resonance are noted; the mean squares of the currents for several wave-lengths differing not more than 5 or 6 per cent. from the resonance wave-length are then ascertained. Thus, supposing the latter to be 500 metres it would be necessary to set the wave meter at the following wave-lengths: 475, 480, 485, 490 on one side and 505, 510, 515 and 520 on the other side of it, and to find the mean square value of the currents corresponding to them. Calling the resonance wave-length 1 and the mean square value of the current at resonance also 1, the other wave-length and currents are reckoned as percentages and plotted as a curve which will assume the form shown in Fig. 192. From a curve so plotted it is possible to tell at a glance whether the oscillations given out by the transmitter under test are badly damped or only feebly damped. If they are badly damped, the curve will not be very steep—that is to say, as the resonance point is receded from, the falling off of the current will not be very marked; but if the damping is small the curve will be very steep and any deviation from the resonance point will be accompanied by a big drop in current. The damping decrement can be found by the aid of the formula $\delta_1 + \delta_2 = \pi x \sqrt{\frac{y}{1-y}}$; δ_1 is the symbol for the decrement of the oscillations, δ_2 for

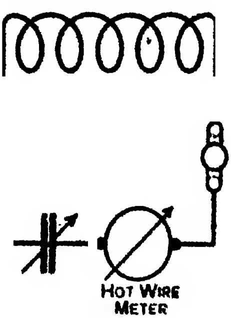


Fig. 188.

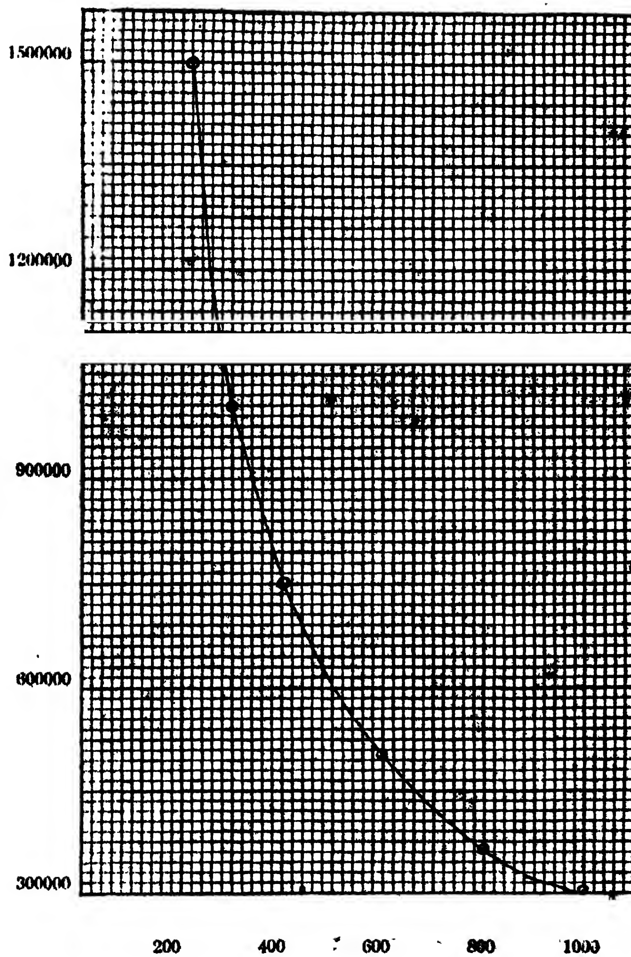


FIG. 189.

Wave-length in metres.

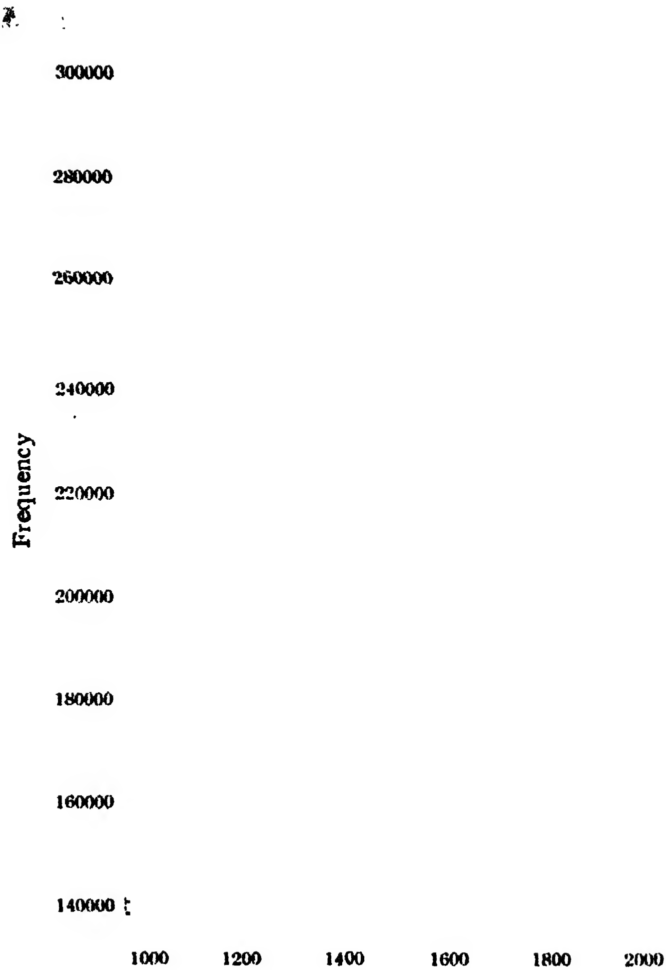


FIG. 190.

Wave-length in metres.

that part of it due to the wave meter itself, $\pi = 3{\cdot}1416$, x the difference between unity and any value of the ratio between the resonance wave-length

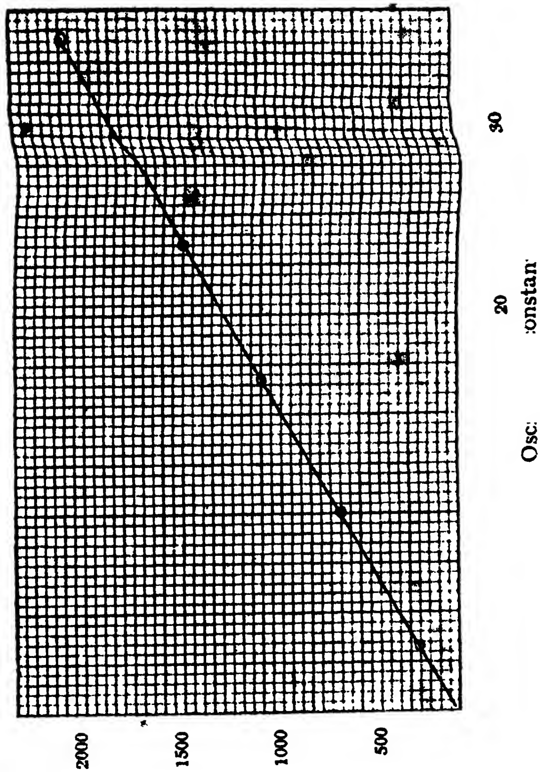


Fig. 191.

Wave-length in meters.

and any other and is read directly from the curve, and y is the ratio between the mean square value of resonance current and any other current. This value is

also to be read from the curve. For use in the above formula several values of x should be taken and the values of y corresponding to them, and as the curve

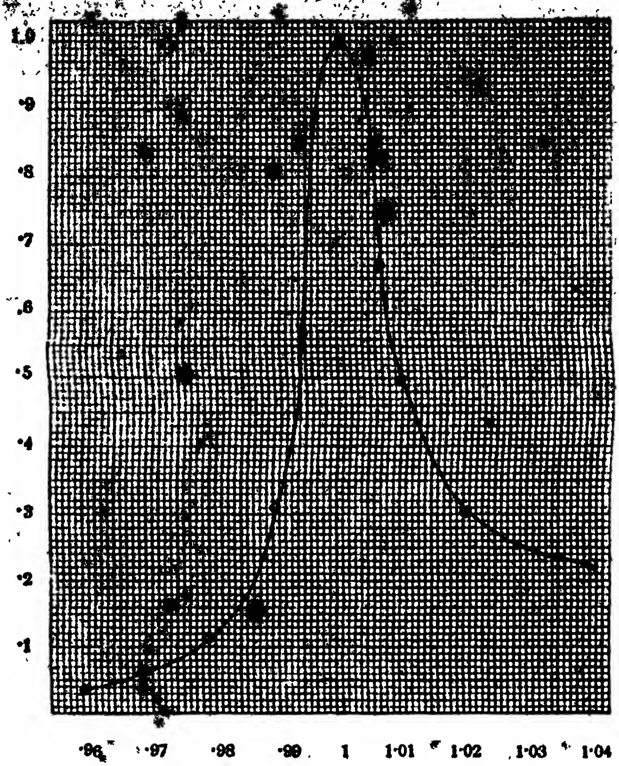


FIG. 192.
Resonance curve.

is not symmetrical, the value of y should be the mean of readings taken from each side of the curve. The values of x and of y so taken are to be averaged and the average value is the one to be used in the formula.

That part of the decrement due to the wave meter itself is very small and can therefore as a rule be

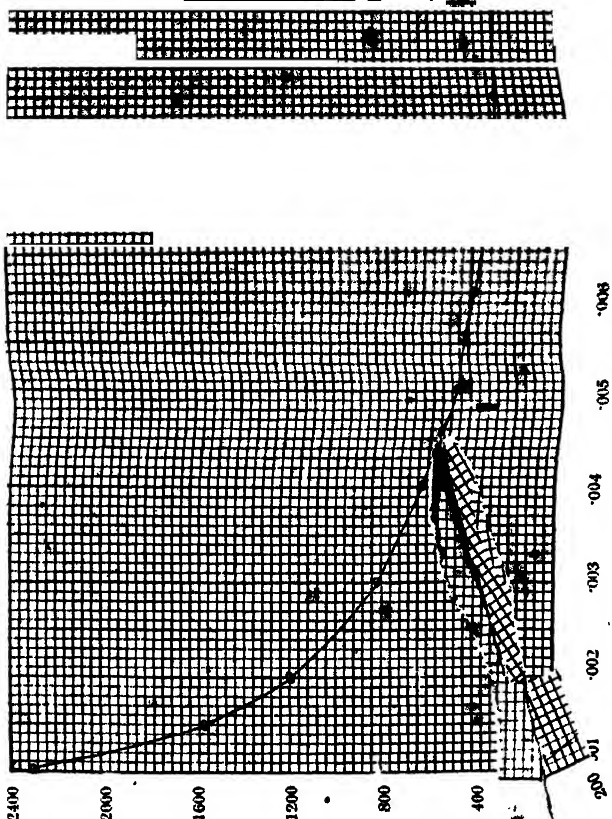


Fig. 193.

Oscillations per train.

neglected. In plotting the resonance cu ... ing two fr coupled spark sender it will be found that ... be t

has a double hump due to the interaction of the primary and secondary circuits which produces oscillations

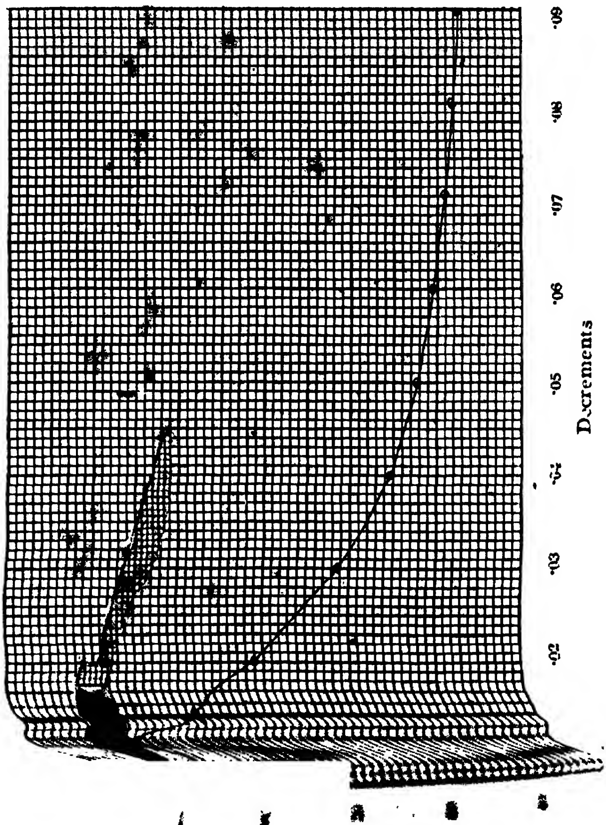


FIG. 104.

Oscillations per train.

frequencies, but the shorter wave-length need
taken into account as its damping is greater

than the longer one, on which account the longer one is always used for the reception of signals.

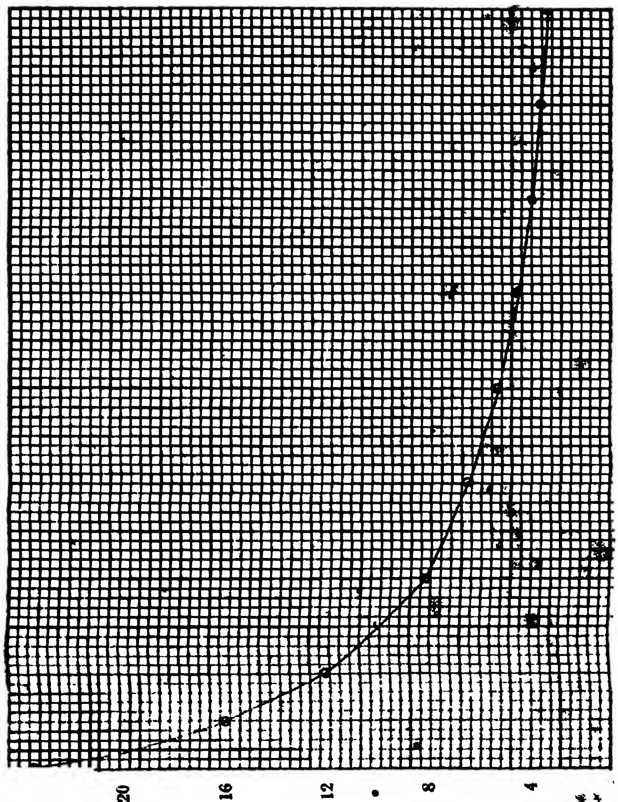


FIG. 195.
Oscillations per train.

ıer and simpler method of ascertaining the the decrements is to set up the wave meter as escribed to observe the wave-length and mean

square value of the current at resonance, and then to observe the wave-length at which the mean square value of the current is reduced to half. From the formula $\delta_1 + \delta_2 = \pi \frac{\lambda - \lambda_1}{\lambda}$, where λ = resonance wave-length and λ_1 = the wave-length at which the mean square current is reduced to half, the sum of the decrements can then be found. For example, suppose that the resonance wave-length is 600 metres and that the mean square current is reduced to one-half when the wave meter is set at 594 metres, the sum of the decrements will approximately equal ·063. In making the measurement by this method it should be noted that the value of λ_1 to be used in the formula is the mean of readings taken on each side of the resonance point.

Curves Showing Number of Oscillations per Train Decrements ·001 to ·9

When the amplitude of a train of waves has fallen to ·01 of the initial or maximum amplitude, it has for all practical purposes ceased to exist. If the decrement of the oscillation is known the number of oscillations per train can be found from the formula $N = \frac{4{\cdot}605 + \delta}{\delta}$, where N = the oscillations per train, $4{\cdot}605$ = the Nap. log. of 100 and δ = the decrement per whole period. If the decrement is reckoned per half period, as is usually the case, the result must be divided by two. The appended curves will show at a glance the number of oscillations per train for decrements from ·001 to ·9.

THE MARCONI DECREMETER

The purpose of this instrument is to give a direct reading of the decrement of electro-magnetic oscillations without the necessity of plotting a resonance curve; this somewhat complicated a comparatively simple operation. The instrument which is diagrammatically shown in Fig. 196 consists of an oscillation circuit composed of a fixed inductance and variable capacity also a small inductance which

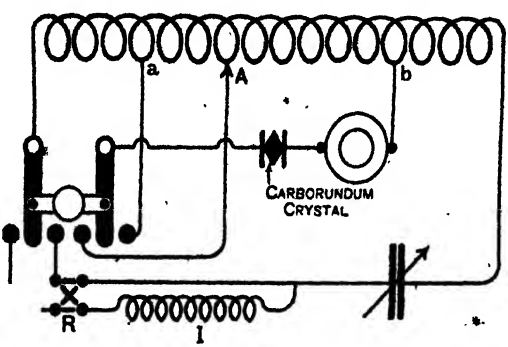


FIG. 196.

Circuits of Marconi decremeter.

may be added to, or subtracted from the inductance by means of a double-pole double-throw switch. The indicating arrangement, which consists of a carborundum crystal and telephone receiver, is tapped across the central portion of the fixed inductance.

If d be the logarithmic decrement and n_1 the frequency of the oscillations under test, and if D be that part of the decrement due to the wave meter circuit and a_1^2 the mean square current induced in it when brought to resonance with the circuit under test, while

a_2^2 is the mean square current induced in it when its frequency is altered to n_2, which must differ not more than 5 or 6 per cent. from the frequency n_1 of the circuit, then as is well known $d+D=\pi\left(1-\frac{n_2}{n_1}\frac{a_2}{\sqrt{a_1^2-a_2^2}}\right)$.

If not, the inductance m of the oscillation circuit of the wave meter which gives the frequency n_1 is altered by the addition or subtraction of a small inductance M to give the frequency n_2, so that $\frac{n_2}{n_1}=\sqrt{\frac{m}{m \pm M}}$, and the detector which is normally connected across a length l of the inductance of the wave meter is, when the small inductance is added or subtracted, connected across a new length L such that the same effect is produced in the detector in the two cases, so that if the potential drop along the inductance is proportional to the length and if the current is proportional to the potential $\frac{a_2}{\sqrt{a^2-a^2}}=\frac{l}{\sqrt{L^2-l^2}}$ and the equation for the sum of the decrements becomes $d+D=\pi\left(1-\sqrt{\frac{m}{m \pm M}}\right)\frac{l}{\sqrt{L^2-l^2}}$, in which the capital letters represent constants of the instrument, so that only the inductance m and length l are required to determine the decrement d of the circuit under test; also if the small inductance M be made a known proportion of the inductance m, which may be done if the adjustment of the circuit is effected by the variation of the capacity, then the term expressing the ratio of the frequencies $\frac{n_2}{n_1}$ becomes a constant, so that only

the length l has to be measured to find the decrement of the circuit under test and the instrument becomes direct reading and may be calibrated in decrements.

To ascertain the decrement of any circuit the following procedure should be adopted—

The decremeter is set up in the vicinity of the circuit under test and the condenser adjusted *till the loudest sound is produced in the telephone, the double-pole switch being over to the right, thus making* L and I (or L) the inductance of the oscillation circuit according to the position of the switch R and causing the length of inductance a, b to be included in the detector circuit. The double-pole switch is then moved over to the left, the result being to add or subtract the inductance I to or from the oscillation circuit and to alter the position of the inductance in the detector circuit to A, b. The switch is now thrown backwards and forwards and the position of the contact A on the inductance varied until an equally loud sound is produced in the telephones with the switch in either position; the variable l in the above equation is thus determined and the decrement can be read directly from the scale of the instrument.

Logarithmic Chart for Calculating the Frequency and Wave-Length of Oscillating Circuits *

In the use of oscillations produced by the discharge of a condenser through an inductance, as in wireless

* Based on an article in *The Indian Telegraphist*. (*By permission*.)

telegraphy, for example, the frequency and wave-length of the oscillations are usually calculated from the values of the inductance and capacity. The formulae used, although simple, become rather tedious if many calculations are required. To simplify and shorten this calculation the straight-line chart shown herewith was designed to give the result at one operation.

The formula for representing the frequency of a condenser discharge should really include the resistance of the oscillating circuit, but since the resistance over a considerable range has only a very slight effect on the frequency, and in any practical oscillating circuit the *resistance* must be kept low on account of the losses, it is usual and quite permissible to neglect the resistance.

The formula for frequency when the resistance is neglected is—

If the inductance is expressed in centimetres and the capacity in microfarads (1) $n = \dfrac{5{\cdot}033 \times 10^6}{\sqrt{CL}}$, where $n =$ the frequency, L the inductance and C the capacity.

The velocity of propagation of electric waves being the same as light—that is, 3×10^8 metres per second—the relation between frequency and wave-length is (2) $L = \dfrac{3 \times 10^8}{n}$, where $L =$ wave-length in metres and n the frequency. The chart has been laid out from formulae (1) and (2). It consists of three logarithmic scales so proportioned and located with respect to each other as to give the required result by a single operation. As drawn they give directly the values of wave-length from 200 to 2,000 metres, for inductance from 10 microhenries to 100 microhenries and capacities

from 1,000 to 10,000 centimetres. If preferred the middle scale could be marked out so as to give frequency instead of wave-length; likewise, if found more convenient, the inductance could be expressed in centimetres and capacity in microfarads. To use the chart a straight edge is placed so as to cross the selected value of the inductance on the upper scale and the selected value of capacity on the lower scale. The intersection of the straight edge with the middle scale then shows the wave-length. The chart can also be used to determine what inductance or capacity to use with a given inductance or capacity to produce a certain wave-length.

To find the required inductance place the straight edge so as to connect the value of the capacity on the lower scale with the wave-length on the middle scale. The inductance is then indicated by the point at which the straight edge crosses the upper scale. To find the capacity place rule so as to connect inductance on upper scale with wave-length on middle scale: the required capacity

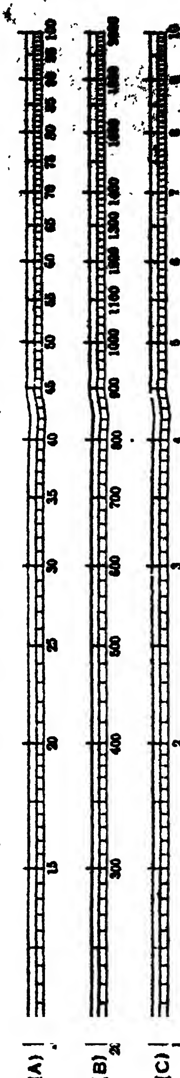


FIG. 197.

A=Inductance in microhenries. B=Wave-length in metres. C=Capacity in jars. 1 jar=1,000 centimetres.

is then indicated by the point at which the lower scale is crossed by the straight edge.

INDUCTANCE

The unit of inductance is the henry, equal to 10^9 absolute units, and a coil of wire is said to possess unit inductance when the current through it varying at the rate of 1 ampère per second induces in it an electromotive force of 1 volt. The henry is far too large a unit for the inductances employed in Radio-Telegraphy, it is therefore customary to use a sub-unit, the millihenry or the microhenry, which equals one-thousandth and one millionth of a henry respectively: the inductance is also frequently expressed in absolute units or centimetres. The inductance of a circuit from which all magnetic material is absent depends on its geometric form, but if magnetic material is present, as when the coil is wound on an iron core, the inductance is also a function of the current. The inductance to some extent varies with the frequency of the current alternations, and the low-frequency or steady-current value is larger than the high-frequency value. The reason of this is, that as the frequency increases the current is no longer evenly distributed over the section of the wire, but tends to confine itself to the surface. Anything that upsets the equal distribution over the cross-section of the wire diminishes the inductance: the variation with differing frequencies is very marked in a closely wound coil, especially if it has more than one layer. The calculation of the inductance of a coil from its dimensions is very difficult and can seldom be carried out with any degree of accuracy.

An easy method of ascertaining the high-frequency inductance of a coil is to join it in series with a known capacity and spark-gap, to excite the oscillatory circuit so formed by means of an induction coil and measure the wave-length. Then by the use of the formula $\lambda = 59{\cdot}6\ \sqrt{CL}$ (where $\lambda =$ wave-length in metres, $C =$ capacity in microfarads and $L =$ inductance in centimetres) the value of the inductance can be found.

Coefficient of Coupling

When two oscillatory circuits are coupled together we have seen that oscillations of two frequencies are set up, one having a frequency greater and one less than the natural frequency of the circuits when uncoupled. If the coupling is close the difference between the frequencies will be great, but as the coupling is made looser they approach, till with very loose coupling they merge into one. The coefficient of coupling denotes the ratio between the coefficient of the mutual inductance of the circuits and the square root of the product of the inductances of the two circuits taken separately. The closest coupling possible theoretically would be 1, but in practice this is never attainable, because the inductance in the radiating circuit is not concentrated in the coil which forms the secondary of the oscillation transformer, but is distributed over the whole length of the aerial.

The coefficient of coupling can be ascertained by means of the wave meter; the procedure is as follows: first measure the two wave-lengths which result from the coupling of the circuits, then from the formula $K = \frac{\lambda_1^2 - \lambda_2^2}{\lambda_1^2 + \lambda_2^2}$, where $K =$ coefficient of coupling and λ_1

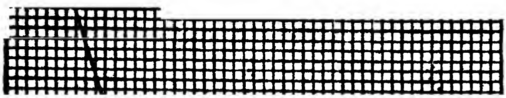
and λ_2 the wave-lengths; it is a simple matter to ascertain the coupling coefficient. As an example, suppose the shorter of the wave-lengths was 300 and the longer 600 metres K would equal ·6; if the coefficient of coupling is greater than ·5 the coupling is said to be close, and if below ·5 it is said to be loose. In the example given the coupling is close because it exceeds ·5.

Calibration of Receiving Circuits

It is a great convenience to the operator to possess a calibration curve for his receiver, for suppose he is on the look-out for signals of a given wave-length the position of resonance for which is unknown to him, he must be continually searching round till communication is established, which in the case of a ship may be many hours or even a day or two supposing she is delayed by unforeseen circumstances; whereas if he is in possession of the calibration curve he can at once adjust his circuits and then stand by.

Also assuming that the receiver is of the three-circuit type, the calibrated intermediate circuit can be used as a wave meter to measure the wave-length of his own transmitter. To plot such a curve he should proceed as follows: if the receiver consists of two circuits he should excite one of them by means of a small induction coil, the second circuit meanwhile being uncoupled, and setting the pointer of the variable condenser in various positions, say, every 20°, or if it is the inductance that is variable the slider will be moved twenty or thirty turns at a time and by means of the wave meter the wave-lengths corresponding to these positions found, the second circuit is then treated

in like manner and the values so found are plotted, as in Fig. 198. The curves will generally be found to be



rather steep at the origin and then to flatten off towards the end. In using the curves it should be noted that when the coupling is re-established between the circuits it will slightly modify the wave-lengths as shown on the curve, but the difference in adjustment required to bring the circuits absolutely into tune will be very small.

Measurement of Earth Plate Resistance

The measurement of earth plate resistance is carried out as follows—

In laying down the earth wires half should be brought to one terminal in the cabin and the other half to another terminal (normally, of course, these terminals are connected together); between these terminals a galvanometer and battery are joined and the current noted, the resistance can then be found by the aid of Ohm's law $C = \frac{E}{R} \therefore R = \frac{E}{C}$, where C = current, as read from galvanometer, E = voltage of battery, and R = the total resistance of the circuit. If the internal resistance of the battery is subtracted from this the remainder will be the earth plate resistance. In making the measurement it is advisable to use large secondary cells, as the internal resistance of these is negligible.

Strength of Received Signals

Assuming that the detector in use, is of the thermo-electric type, the strength of incoming signals can be measured by means of a sensitive moving-coil galvanometer, which should be joined in place of the telephones. As, however, the signals are usually read from a telephone receiver and, as we have seen in a

previous chapter, the telephone is most sensitive to certain frequencies, it will be seen that weak oscillations of the right frequency may produce a greater effect in the telephone than stronger oscillations of a different frequency. In the majority of cases also it is only a comparison of the strength of signals that is required, in which case the shunted telephone method will be found to answer the purpose; the procedure is as follows: A resistance variable in small steps is joined in series with a switch across the telephone terminals of the receiver. The operator at the sending station depresses his key and the observer at the receiving end having tuned the signals in to their maximum strength closes the switch and so puts the resistance in shunt to the telephones. Starting with the maximum resistance he decreases it step by step until the signals are just audible; then, knowing the resistance of the telephones and the resistance of the shunt, the signal strength can be expressed as so many times audibility. For instance, supposing that the shunt resistance just equals that of the telephones, the current from the thermo-cell dividing as it does in inverse proportion to the resistances of the two branches of the circuit, it is evident that half flows through the telephone and half through the shunt, therefore the strength of signals can be expressed as 2. Now suppose that the shunt resistance was such that nine-tenths of the current flowed through it, the signal strength in that case would be 10.

Energy in Aerial

The radiation from an open oscillatory circuit withdraws energy from it just as if a resistance were

included in the circuit. To measure the energy in such a circuit, the following procedure should be adopted—

In the aerial circuit a calibrated hot wire ampère meter and two single-pole double-throw switches should be included, as in Fig. 199. An air condenser,

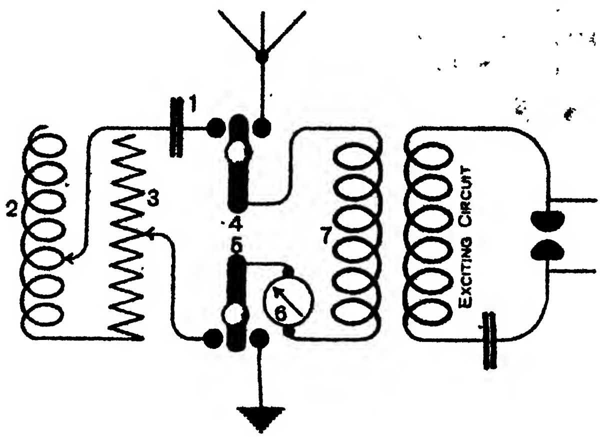


FIG. 199.

Measurement of energy in aerial.

1. Condenser of capacity to aerial. 2. Inductance. 3. Non-inductive resistance. 4 and 5. Switches. 6. Hot wire ampère meter. 7. Secondary of oscillation transformer.

having a capacity equal to the capacity of the aerial, and an inductance coil, having an inductance equal to the aerial, should be connected together in series and with a variable non-inductive resistance, as in Fig. 199. The two switches should first be placed to the right so as to connect to antennae and earth and the current registered on ampère meter noted. Next, place the switches over to the left and vary the non-inductive resistance till the same reading is obtained

on the ampère meter. With the switches in this position it will be seen that the ampère meter is now in a closed or non-radiating circuit having the same frequency as the aerial circuit, and that a resistance having an energy-absorbing power equal to the radiation from the aerial has been included in the circuit. The amount of the resistance included in the circuit is sometimes called the radiation resistance of the antennae, and simply means the resistance which, under given conditions, absorbs the same amount of energy as is radiated from the circuit. The energy radiated from the aerial circuit can be found by multiplying the radiation resistance of the circuit by the mean square value of the current. The result so obtained is not quite accurate, as the aerial wires and the earth connection have some resistance which is included in the radiation resistance when found by the above method; the amount of this would have to be ascertained and subtracted if we wished to get an absolutely accurate result.

CHAPTER XIII

DIAGRAMS

Their Interpretation and Preparation

A DIAGRAM is a drawing which expresses the electrical qualities of a piece of apparatus or of a circuit by means of conventional symbols. These symbols are not necessarily a picture of the apparatus represented, though in some cases they do bear a rough resemblance as in the case of the symbols used to show a fuse. For instance if we wish to represent a cell, instead of drawing the containing vessel and the elements of the cell, we should show it by means of the symbol 2, Fig. 200, the negative pole being represented by a short thick line and the positive pole by a longer and thinner line.

If we wish to show that a number of pieces of apparatus are connected together, we connect their terminals by lines; the relative sizes of the connecting wires can if necessary be shown by using lines of different thickness. When two lines cross, but are not in electrical connection, one is looped over the other, as in 32, Fig. 200. 31, Fig. 200, indicates that the wires are in electrical connection at that point.

In the preparation of a diagram, the aim should always be to make it as clear as possible. To this end the same symbol for each piece of apparatus should be used throughout. The lines connecting the various instruments should never be taken obliquely across the drawing, but always in a horizontal or vertical

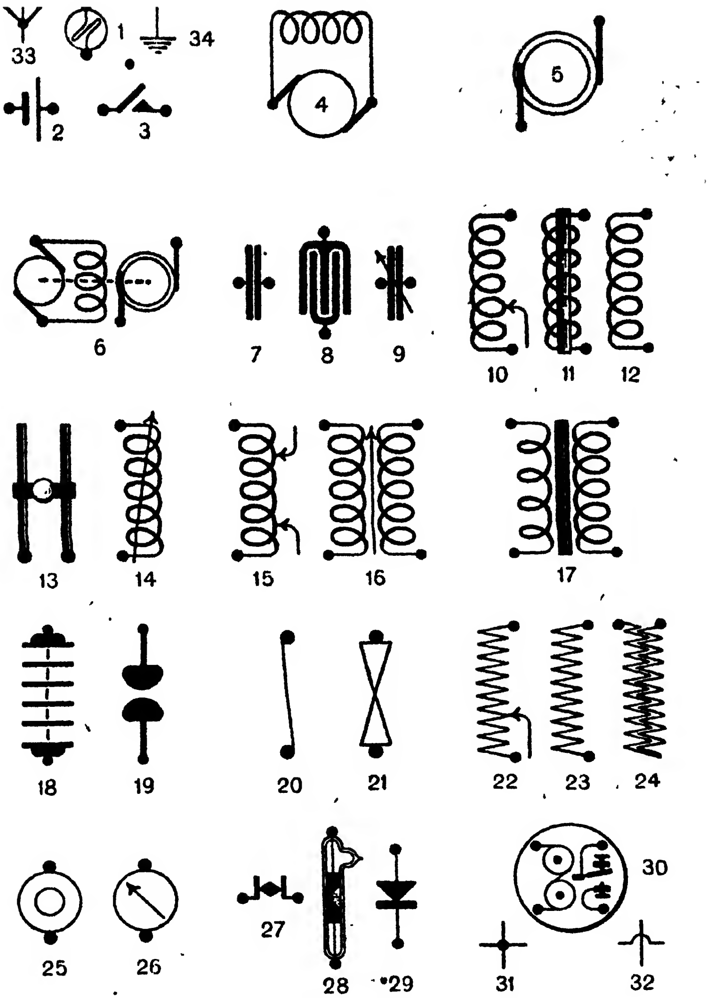


FIG. 200.

mp resistance
ll
rse key or switch
unt - wound dynamo or
motor
ernator
tary converter
ndenser (fixed capacity)
ndenser (fixed capacity)
riable condenser
luctance (variable in
tens)

12. Inductance
13. Sliding inductance
14. Variometer (continuously variable inductance)
15. Auto-transformer
16. Oscillation transformer
17. Alternating - current transformer
18. Quenched spark-gap
19. Spark-gap
20 and 21. Fuses

24. Non-inductive resistance
25. Telephone receiver
26. Measuring instrument
27. Carborundum detector
28. Coherer
29. Thermo-electric detector
30. Relay
31. Wires in electrical connection
32. Wires crossing but not connected

direction; also, they should be so arranged as to keep the crossings at a minimum. Reference to the diagrams in this book will make clear what is meant.

The drawing should be so arranged as to fairly fill the whole space, this not only makes for clearness but improves its appearance.

The symbols given in Fig. 200 are those most commonly used to denote the various pieces of apparatus.

CHAPTER XIV

REGULATIONS AND INSTRUCTIONS FOR SHIPS AND STATIONS LICENSED BY H.M. POSTMASTER-GENERAL

Speed of Transmission—Power—Wave Lengths—Obligation to Communicate—Priority of Messages—Calling—Preliminary Correspondence—Distress Signals—Admiralty Signalling—Controlling Station

SPEED OF TRANSMISSION

THE apparatus must be capable of transmitting and receiving at least twenty words per minute. The speed of transmission must under normal circumstances be not less than twelve words per minute, five letters counting one word.

POWER

New installations bringing into play an energy of more than 50 watts shall be equipped in such a way that it may be possible easily to obtain several ranges less than the normal range, the shortest being approximately 15 nautical miles. Installations already in existence bringing into play an energy of more than 50 watts shall be transformed as far as possible in such a manner as to satisfy the foregoing requirements. The power (measured at the terminals of the generator) must not in ordinary circumstances exceed 1 kilowatt. Larger power may be used if the ship is under necessity to communicate over a distance greater than 200

nautical miles from the nearest coast station, or if in consequence of exceptional circumstances communication can only be secured by increase of power.

Minimum Power to be Used

All stations are bound to exchange messages with the minimum power consistent with effective communication.

Wave-Lengths

Two wave-lengths, one of 600 and the other of 300 metres, are allowed for general public correspondence. Every coast station open to this service must be equipped in such a way as to be able to use these two wave-lengths, one of which will be indicated as the normal wave-length of the station. A coast station is sometimes authorised to use a wave-length not exceeding 600 or else exceeding 1,600 metres for communication of a special kind.

Stations used exclusively for the despatch of signals intended to determine the position of ships must not use wave-lengths exceeding 150 metres. Every ship station must be equipped in such a way as to be able to use the 600 and 300 metre wave-lengths, the 600 metre being the normal wave-length, and which may not be exceeded in transmission.*

During the whole time that it is open, every ship station must be able to receive calls made on its normal wave-length. Ships of small tonnage, on which it would be materially impossible to use a 600 metre wave for transmission, may be authorised to exclusively

* Except for long-distance communication in exceptional circumstances, when a wave-length of 1,800 metres may be used.

employ the 300 metre wave for the purpose, but must be able to receive by means of the 600 metre wave-length.

Communication between any two stations must be carried out on both sides by means of the same wave-length. If in a particular case communication is difficult they may by mutual consent change to the other regulation wave-length. Both stations shall resume their normal wave-lengths when the exchange of messages is finished.

Obligation to Communicate with all Systems

All coast stations (except those exempted by their respective governments) are bound to interchange radio-telegrams with ships irrespective of the system of Radio-Telegraphy employed. Similarly ships are bound to interchange messages with coast stations without regard to system. British ships at present are not bound to exchange messages with other ships, whether British or foreign, except in cases of distress, when the obligation is universal, and such messages must be given priority.

Priority of Messages

Priority must be assigned first of all to messages of distress, then to messages of the British Admiralty and other British Government departments and to the messages of other governments; then to service messages, and finally to ordinary correspondence. Ordinary messages take precedence according to their time of handing in.

CALLING

As a general rule, it is the ship which calls the coast station. Generally the ship should not call until within 75 per cent. of the normal range of the coast station; the wave-length used must be the normal one of the coast station with whom communication is desired. Suppose a ship whose call signal is DHB wishes to call a station whose call is LNS, she would proceed as follows: Having listened to ascertain that the station is not engaged the ship would signal —.—.— LNS LNS LNS —- - - DHB DHB DHB, and the coast station would reply thus: —.—.— DHB DHB DHB — - - - LNS —.— if she were ready to communicate; and if she were not would reply assigning a time at which she would, in which case her reply would be as follows: —.—.— DHB DHB DHB — - - - LNS . — - - - - 20 minutes .—.—.

If a station as the result of a thrice-repeated call does not reply the call may only be renewed after the lapse of fifteen minutes. (This rule does not apply to cases of distress.)

PRELIMINARY CORRESPONDENCE

The ship first signals—

(1) Her approximate distance from the coast station in nautical miles.

(2) The position of the ship given in a concise form and adapted to the circumstance of the individual case.

(3) The next port at which the ship will touch.

(4) The number of radio-telegrams if they are of

normal length, or the number of words if they are of exceptional length.

The speed of the ship in nautical miles shall be given at the special request of the coast station.

Distress Signal

Ships in distress make use of the following signal: . . . — — — . . . repeated at short intervals. As soon as a station receives the distress signal it must suspend all correspondence and not resume it until it has made sure that the communication consequent on the call for assistance has been completed. When a ship in distress adds, after a series of distress signals, the call sign of a particular station, the duty of answering the call rests with that station alone. Failing any mention of a particular station any station that receives the call is bound to answer it.

Admiralty Signalling

The signal — . . — . . — . . — indicates that a British man-of-war is calling a British coast station and has a message to transmit to the Admiralty. On receipt of such a signal, the station called must suspend all other business (except that which may concern a vessel in distress) in order to deal with the message from the man-of-war. Any other station (ship or shore) must suspend working so far as may be necessary to ensure satisfactory communication between the man-of-war and the station called.

Controlling Station

The shore station is in all cases the controlling station, and arranges order of working.

CHAPTER XV

ABBREVIATIONS, CODES, ETC.

List of Abbreviations to be used in Radio-Telegraph Transmissions—International Morse Code—American Morse Code—Time Signals—Table to convert Course and Bearing into Degrees

LIST OF ABBREVIATIONS TO BE USED IN RADIO-TELEGRAPH TRANSMISSIONS

Abbreviation	Question	Answer or Advice
PRB	Do you wish to communicate with my station by means of the International Code?	I wish to communicate with your station by means of the International Code.
QRA	What is the name of your station?	This station is . . .
QRB	How far are you from my station?	The distance between our stations is . . . nautical miles.
QRC	What are your true bearings?	My true bearings are . . .
QRD	Whither are you bound?	I am bound for . . .
QRF	*Where are you coming from?*	*I am coming from . . .*
QRG	To what company or line of navigation do you belong?	I belong to . . .

Abbreviation	Question	Answer or Advice
QRH	What is your wave-length ?	My wave-length is . . . metres.
QRJ	How many words have you to transmit ?	I have . . . words to transmit.
QRK	How are you receiving ?	I am receiving well.
QRL	Are you receiving badly ? Shall I transmit - - - — 20 times for you to adjust your apparatus ?	I am receiving badly. Transmit - - - — 20 times for me to adjust my apparatus.
QRM	Are you being interfered with ?	I am being interfered with.
QRN	Are atmospherics very strong ?	Atmospherics are very strong.
QRO	Shall I increase my power ?	Increase your power.
QRP	Shall I decrease my power ?	Decrease your power.
QRQ	Shall I transmit faster ?	Transmit faster.
QRS	Shall I transmit slower ?	Transmit slower.
QRT	Shall I stop transmitting ?	Stop transmitting.
QRU	Have you anything for me ?	I have nothing for you.
QRV	Are you ready ?	I am ready. All is in order.

Abbreviation	Question	Answer or Advice
QRW	Are you busy ?	I am busy with another station (or : with . . . .), please do not interrupt.
QRX	Shall I stand by ?	Stand by. I will call you at . . . o'clock (or : when I want you).
QRY	What is my turn ?	Your turn is No. . . .
QRZ	Are my signals weak ?	Your signals are weak.
QSA	Are my signals strong ?	Your signals are strong.
QSB	Is my tone bad ? Is my spark bad ?	The tone is bad. The spark is bad.
QSC	Is the spacing bad ?	The spacing is bad.
QSD	Let us compare watches. My time is . . . What is your time ?	The time is . . .
QSF	Are the radio-telegrams to be transmitted alternately or in series ?	Transmission will be in alternate order.
QSG		Transmission will be in series of five.
QSH		Transmission will be in series of ten.
QSJ	What is the charge per word for . . . ?	The charge per word is . . .

Abbreviation	Question	Answer or Advice
QSK	Is the last radio-telegram cancelled ?	The last radio-telegram is cancelled.
QSL	Have you got the acknowledgment ?	Please give acknowledgment.
QSM	What is your true course ?	My true course is . . .
QSN	Are you communicating with land ?	I am not communicating with land.
QSO	Are you in communication with another station (or: with . . .) ?	I am in communication with . . . (through the medium of . . .).
QSP	Shall I signal to . . . that you are calling him ?	Inform . . . that I am calling him.
QSQ	Am I being called by . . . ?	You are being called by . . .
QSR	Will you despatch the radio-telegram . . . ?	I will forward the radio-telegram.
QST	Have you received a general call ?	Yes (or no), general call received.
QSU	Please call me when you have finished (or: at . . . o'clock) ?	I will call you when I have finished.
QSV	Is public correspondence engaged ?	Public correspondence is engaged. Do not interrupt.
QSW	Shall I increase the frequency of my sparks ?	Increase your spark frequency.

Abbreviation	Question	Answer or Advice
QSY	Shall I transmit with a wave-length of . . . metres ?	Let us change to . . . metre wave-length.
QSX	Shall I diminish my spark frequency ?	Diminish your spark frequency.
QSZ		Send each word twice ; I have difficulty in receiving your signals.
QTA		Send each radio-telegram twice ; I have difficulty in receiving signals (or : Repeat last *radio-telegram* ; reception doubtful).

— · — — · —	Call for all stations.
— · — · (T R)	Signal announcing the sending of indications concerning a ship station.
— — · · — — (!)	Signal indicating that a station is about to send with high power.

EXAMPLES

Station		
A	QRA ?	= What is the name of your station ?
B	QRA Campania	= This is the Campania.
A	QRG ?	= To what Company do you belong ?
B	QRG Cunard QRZ	= I belong to Cunard Line. Your signals are weak.

Station A increases power of its transmitter and sends :

A	QRK ?	= How are you receiving ?
B	QRK	= I am receiving well.
	QRB 80	= Distance between our stations is 80 nautical miles.
	QRC 62	= My true bearing is 62 degrees, etc.

MORSE CODE SIGNALS

Letters

a · —
ä · — · —
á or å · — — · —
b — · · ·
c — · — ·
ch — — — —
d — · ·
e ·
é · · — · ·
f · · — ·
g — — ·
h · · · ·
i · ·
j · — — —
k — · —
l · — · ·
m — —
n — ·
ñ — — · — —
o — — —
ö — — — ·
p · — — ·
q — — · —
r · — ·
s · · ·
t —
u · · —
ü · · — —
v · · · —
w · — —
x — · · —
y — · — —
z — — · ·

Spacing and length of signals:

1. A bar is equal to three dots.
2. The space between the signals which form the same letter is equal to 1 dot.
3. The space between two letters is equal to 3 dots.
4. The space between two words is equal to 5 dots.

Figures

1 · — — — —
2 · · — — —
3 · · · — —
4 · · · · —
5 · · · · ·
6 — · · · ·
7 — — · · ·
8 — — — · ·
9 — — — — ·
0 — — — — —
Bar indicating fraction — — — — — —

The following signals may also be employed to express figures, but only in official repetitions and in the preamble, and in the text of telegrams written entirely in figures :—

1	· —
2	· · —
3	· · · —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— · · ·
8	— · ·
9	— ·
0	—
Bar indicating fraction	— —

Punctuation and other Signs

Full stop	(.)	· · · · · ·
Semicolon	(;)	— · — · — ·
Comma	(,)	· — · — · —
Colon	(:)	— — — · · ·
Note of interrogation, or request for the repetition of anything transmitted which is not understood	(?)	· · — — · ·
Note of exclamation	(!)	— — · · — —
Apostrophe	(')	· — — — — ·
Hyphen or dash	(-)	— · · · · —
Parenthesis (before and after the words) .	( )	— · — — · —
Inverted commas (before and after each word) or each passage placed between inverted commas	("et")	· — · · — ·
Underline (before and after the words or part of phrase)		· · — — · —
Call (preliminary of every transmission) .		— · — · —
Double dash (=) (signal separating the preamble from the address, the address from the text, and the text from the signature) .		— · · · —
Understood		· · · — ·
Error		· · · · · · · ·
Cross (end of transmission) . . .	(+)	· — · — ·
Invitation to transmit		— · —
Wait		· — · · ·
"Received" signal		· — ·

AMERICAN MORSE CODE

A	· —	O	· ·	1	· — — ·
B	— · · ·	P	· · · · ·	2	· · — · ·
C	· · ·	Q	· · — ·	3	· · · — ·
D	— · ·	R	· · ·	4	· · · · —
E	·	S	· · ·	5	— — —
F	· — ·	T	—	6	· · · · · ·
G	— — ·	U	· · —	7	— — · ·
H	· · · ·	V	· · · —	8	— · · · ·
I	· ·	W	· — —	9	— · · —
J	— · — ·	X	· — · ·	0	———
K	— · —	Y	· · · ·	.	· · — — · ·
L	———	Z	· · · ·	?	— · · — ·
M	— —	&	· · · ·		
N	— ·				

TIME SIGNALS

Time signals are sent out daily at noon and midnight Greenwich mean time by the German station at Norddeich (K.N.D.).

The signals consist of groups of dots (five dots to the group) sent out at seconds intervals. The order of signalling is as follows :—

Preliminary Signals

About 11 h.	53′	0″	Tuning Vs for about 1 or 2 minutes
	57′	50″	— · — · —
		55″	KND
	58′	0″	MGZ (mittlerer Greenwicher Zeit
	58′	40″	— · — · —

Time Signals

11 h.	58′	46″	First dot of first group
		50″	Last ditto
	58′	56″	First dot of second group
	59′	0″	Last ditto
	59′	6″	First dot of third group
		10″	Last ditto

	59′ 36″	First dot of fourth group	
	40″	Last	ditto
	59′ 46″	First dot of fifth group	
	50″	Last	ditto
	59′ 56″	First dot of sixth group	
12 h.	0′ 0″	Last	ditto
About 12 h.	0′ 5″	– — – — –	
		Sometimes followed by weather reports.	

The wave-length used is about 1,800 metres.

Table to Convert Course and Bearing into Degrees

The true bearing of a ship from a coast station can be stated in degrees reckoned "clockwise" from north round through east, south and west. Thus, if the ship's bearing from the coast station is *anything* between north and east the number to be signalled would be between 0 and 90 (A, Fig. 201). Similarly, if it is between east and south the number would be between 90 and 180 (B, Fig. 201). Between south and west the number would be between 180 and 270 (C, Fig. 201); between west and north the number would be between 270 and 360 (D, Fig. 201). Similarly, if the ship's course is between north and east the number to be signalled is between 0 and 90; east and south, the number is between 90 and 180; south and west, the number will be between 180 and 270; west and north, the number is between 270 and 360.

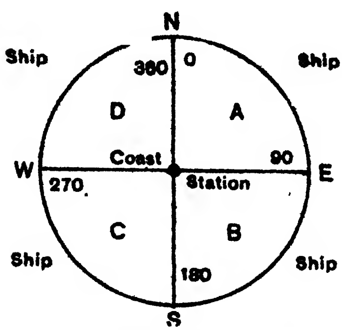


Fig. 201.

To facilitate the conversion of bearings and course into the number of degrees to be signalled, a table is given in which either the bearing of the ship from the coast station or the bearing of the coast station from the ship can be looked out and the number of degrees to be signalled seen at a glance. The course must be looked out in the same column as the bearing of the ship from the coast station.

Table to Convert Bearing and Course into Degrees

Course or Bearing of Ship from Coast Station		Bearing of Coast Station from Ship		Degrees to be Signalled
North	– –	South	– –	0°
N. 10° E.	– –	S. 10° W.	– –	10°
N. 20° E.	– –	S. 20° W.	– –	20°
30° –	– –	30°	– –	30°
40° –	– –	40°	– –	40°
50° –	– –	50°	– –	50°
60°	– –	60°	– –	60°
70° –	– –	70°	– –	70°
80° –	– –	80°	– –	80°
East	– –	West	– –	90°
S. 80° E.	– –	N. 80° W.	– –	100°
S. 70° E.	– –	70°	– –	110°
60° –	– –	60°	– –	120°
50° –	– –	50°	– –	130°
40° –	– –	40°	– –	140°
30° –	– –	30°	– –	150°
20° –	– –	20°	– –	160°
10° –	– –	10°	– –	170°
South	– –	North	– –	180°
S. 10° W.	– –	N. 10° E.	– –	190°
20° –	– –	20°	– –	200°
30° –	– –	30°	– –	210°
40° –	– –	40°	– –	220°
50° –	– –	50°	– –	230°
60° –	– –	60°	– –	240°
70° –	– –	70°	– –	250°
80° –	– –	80°		260°
West	– –	East		270°

Course or Bearing of Ship from Coast Station		Bearing of Coast Station from Ship		Degrees to be Signalled
N. 80° W.	- -	S. 80° E.	- -	280°
70° -	- -	70°	- -	290°
60° -	- -	60°	- -	300°
50° -	- -	50°	- -	310°
40° -	- -	40°	- -	320°
30° -	- -	30°	- -	330°
20° -	- -	20°	- -	340°
10° -	- -	10°	- -	350°
North	- -	South	- -	360° or 0

CHAPTER XVI

LOCALISATION OF FAULTS

THE faults which may occur in the circuits of a wireless transmitter or receiver fall mainly under two heads: breaks or short-circuits.

As regards the transmitter, the indications as to the nature and whereabouts of the fault are so clear no difficulty should be experienced in quickly tracing and rectifying them. The indications on the receiver are not so clear, but if the circuits are examined in a systematic way no difficulty should be found in ascertaining what is the matter.

The fact that the Marconi 1½ kw. set is in such general use practically, and also for examination purposes, has induced us to select it as an example for treatment, though much of what follows is of perfectly general application.

The transmitter of this set consists of five circuits—namely, the direct-current circuit, low tension alternating-current circuit, high tension alternating-current circuit, closed oscillatory circuit and open oscillatory circuit; each of which we shall treat separately and in the order named.

DIRECT-CURRENT CIRCUIT

This circuit consists of D.C. side of rotary converter, starting switch and field regulating resistance, connected together, as shown in Figs. 61 and 66. Let us suppose that the main switch having been closed and the handle of starter brought to first stop the machine

fails to start, this may be due to a break either in the field or armature circuits. If the break (most probably due to the lifting of brushes on commutator) is in the armature circuit it will be indicated by the guard lamp on D.C. side of converter lighting brightly, because the full voltage of the direct-current supply is now across its terminals. Normally, this lamp is very dim until the machine has acquired considerable speed.

If the break is in the field circuit it will be indicated by the inability of the no-load release, which forms part of the field circuit, to attract and hold a small piece of iron—for instance, a latchkey, or blade of a penknife—applied to its poles. A break in the field circuit is also indicated by the vicious arcing which takes place between the arm of starting switch and first-contact piece of starter, when the former is allowed to move back to the off position. The break is most likely due to a terminal disconnection, and the two terminals on the field resistance, the two terminals beneath the no-load release, the terminal marked F on the starting switch and the field terminal on the rotary converter, should therefore be examined. If these are found to be all right, each piece of apparatus in the circuit and each lead, should be tested for continuity by means of the galvanometer and cell.

Low Tension Alternating-Current Circuit

If after the machine is started the pilot lamp and A.C. guard lamp fail to light, this is a clear indication either that the filaments of the lamps are broken, the A.C. brushes are lifted from the slip-rings, or that the leads connecting them have been disconnected or broken.

If (the pilot lamp being alight) there is no reading on the ampère meter and no spark when the Morse key is depressed, this indicates that there is a break in the circuit probably due to a blown fuse or to a terminal disconnection. The break should be located by means of the galvanometer and cell and is most conveniently done in the following way. First test between upper right-hand contact of double-pole switch on A.C. switchboard and bottom terminal of right-hand fuse; a deflection will indicate that the circuit through the ampère meter and fuse is all right. Next test between left-hand upper contact of D.P. switch and bottom terminal of left-hand fuse; a deflection will indicate that this section of the circuit is all right. The leads from the galvanometer and cell should now be connected to the bottom fuse terminals, and first the Morse key and then the magnetic key depressed; if a deflection is obtained on the depression of one key, but not on the other, it will indicate that the contacts of the key failing to give a deflection are dirty or that some insulating material has been introduced between them. If a deflection cannot be obtained by the depression of either key it indicates either that both sets of contacts are dirty or that there is a break or disconnection in the section of the circuit between the two bottom terminals of A.C. switchboard. Examine all terminal connections and if necessary test each piece of apparatus and lead separately with galvanometer.

High Tension Alternating-Current Circuit

The ampère meter, although not in this circuit, will again be found serviceable in indicating the existence and nature of faults. If, on closing the Morse key, the

machine of course being in motion, only a very small reading is obtained on ampère meter (1 or 2 amp.), and no spark at discharger, the fault indicated is that no load is being taken from the secondary of the alternating-current transformer, which may be due either to a break in the connecting leads or in the secondary windings of the transformer, or more probably to a terminal disconnection. See that the secondary terminals are correctly connected to each other, and through air core chokes to the spark-gap. The reason that only a small reading is obtained on ampère meter when no load is taken from the secondary of the transformer is that the primary windings are acting in the same way as the reactance regulator and reducing the current in the circuit. A short circuit on the transformer will be indicated by a reading equal to or somewhat in excess of the normal reading and by the absence of a spark at the discharger. The short may be due to the spark-gap being closed or to a metallic connection being formed by the coming together of the connecting strips owing to the removal of the insulating material normally between them or to the short-circuiting of the condenser in the closed circuit.

Closed Oscillatory Circuit

A break in the closed oscillatory circuit will be indicated by a silent discharge at the spark-gap, the ampère meter reading being about normal.

Open Oscillatory Circuit

The most vulnerable part of this circuit is the aerial, the insulation of which may be bad, or the aerial itself, or some portion of it, may be blown adrift during a gale; in either case failure of tuning

lamp to give normal indication will show that something is wrong. A direct earth, as, for instance, when the antennae is in contact with the mast or guys of the ship, may be tested for by disconnecting the earth wire and inserting galvanometer and cell, a deflection indicating that the aerial is making earth.

In carrying out these tests the short-circuiting plug of the ampère meter must be removed, and care should be taken that the galvanometer is in good working order.

For the convenience of students the indications of the various faults on the transmitter have been tabulated, and should be committed to memory.

Faults on Transmitter Marconi $1\frac{1}{2}$ Kw. Set
Emergency Transmitter

Symptoms.	Fault Indicated.	Cure.
Machine fails to start. D.C. guard lamp lights brightly.	Brushes on D.C. side of converter lifted.	Replace.
Machine fails to start. Flash between arm of starting switch and first stop when handle released.	Break in field circuit.	Examine all terminal connections and test apparatus and leads with galvanometer, if necessary.
Pilot lamp on A.C. switchboard alight, no spark at discharger and no reading on ampère meter when Morse key depressed.	Break in low-tension A.C. circuit.	Trace with galvanometer and repair.
Pilot lamp alight, small reading on ampère meter when Morse key closed.	Break on high-tension A.C. circuit.	Examine terminal connections and leads.

Symptoms.	Fault Indicated.	Cure.
Pilot lamp alight, normal reading on ampère meter, spark at discharger when *Morse key closed.*	Short on secondary of A.C. transformer.	Trace and remove.
Pilot lamp alight, normal reading on ampère meter, silent discharge at spark gap.	Break in closed oscillatory circuit.	Examine terminal connections.

NOTE.—Short-circuiting plug of ampèremeter must be removed when carrying out these tests.

Faults in the accumulators have already been dealt with in Chapter II, and the circuits of the coil and switchboard can be tested for continuity by means of the galvanometer and cell. Reference to the diagrams in Chapter VI will show the points between which to test.

THE RECEIVER

As we have already seen in Chapter V, the production of a sound in the telephones when the buzzer key is depressed is no guarantee that the receiving circuits are all right, and that signals emanating from a distant station could be received. The second buzzer test described in Chapter V should therefore be applied. A fault which not infrequently occurs is the short-circuiting of the earth-arrester spark-gap due to the plates coming into contact or to the bridging of the gaps by particles of conducting matter.

A convenient way of testing for a shorted earth-arrester is to set the aerial tuning condenser at short (the change-over switch being on the standby position), and then if no sound is produced in the telephones by

the buzzer when aerial tuning inductance is at zero, but a sound is produced when some of the inductance is inserted, the operator may be sure that the micrometer gap is screwed down or the earth-arrester gap shorted. The reason for this will be quite plain after a few minutes' study of the conditions prevailing. If (the condenser being at short and the inductance at zero) the earth-arrester gap is shorted we have in parallel with the primary winding of the magnetic detector an alternative path for the oscillatory currents set up by the buzzer having a much lower inductance than that of the detector primary.

The oscillatory currents will divide in inverse proportion to the inductances of the paths, therefore they will be shunted out from the primary winding of the detecter by the low self-inductive shunt which is across it. When some of the aerial tuning inductance is inserted the conditions are altered, and the inductance of the shunt is now greater than that of the primary winding, therefore the greater part of the oscillatory current passes through it and a sound is produced in the telephone receiver.

THE MAGNETIC DETECTOR

The faults most likely to occur are the breaking of one or other of the windings. The break may be located by means of the galvanometer and cell, and if it is not convenient to repair or substitute a fresh coil the operator should change over to the second set of coils on the detector.

THE TELEPHONES

The telephones are best tested by means of the galvanometer and cell. If a deflection is obtained but

no sound is produced this indicates either that the diaphragms are jammed or that the magnet windings are short-circuited. Examine each receiver to see that the diaphragms are clear of the magnet poles, after which detach the wires from the telephone terminals and test again each earpiece separately. If a sound is now produced the short circuit is in the flexible cords and others should be substituted. If no deflection is obtained on the galvanometer, and no sound produced, this indicates a break in the leads or in the winding of one of the phones. Test each earpiece separately and if only one of them is broken down working can be carried on by putting both leads on the damaged earpiece on one terminal. The operator should be careful to note that the contacts which short-circuit the telephones when transmitting do not remain closed when the Morse key is lifted.

GLOSSARY

Aerial. That part of a radio-telegraph installation the function of which is to radiate, or to absorb, the energy of electro-magnetic waves. It consists essentially of one or more conductors some portion of which must be in a vertical position.

Aerial, Plain. An open, or good radiating circuit, in which the oscillations are directly excited. It may consist of a single vertical conductor.

Alternating Current. A current which varies periodically in magnitude and direction.

Alternator. *A dynamo electric machine, used for the production of alternating currents.*

Ampère. The unit of current, one coulomb per second.

Amplitude. The amplitude of an alternating current, or alternating voltage, is the maximum value attained during any half-cycle.

Angle of Lag. The number of degrees through which the armature of an alternator rotates, between the attainment of maximum volts and maximum ampères. (The time taken for 1 cycle being = 360°.)

Aperiodic Circuit. A non-oscillatory, or dead-beat circuit, due to the resistance of the circuit being great.

Arc. A luminous discharge through a gas, the conductivity of which is chiefly dependent on particles torn from one or both of the electrodes.

Asynchronous. A term applied to A.C. Motors, in which there is no relation between the speed of the armature and the frequency of the alternating current driving it. Also applied to a rotary spark gap, in which there is no time relation between the spark and the phase of the alternating voltage, as, for instance, when the gap is rotated by a separate motor.

Audibility. The strength of the signals on a wireless receiver can be expressed as so many times audibility.

Audio-Frequency. Alternating currents having a frequency within the limits of audibility (less than 20,000 cycles per second).

Columb. The unit of electrical quantity (ampère second).

Auto-transformer. A transformer having a single coil, part of which is common to two circuits.

Battery. Two or more cells, either primary, or secondary, connected in series or in parallel with each other. Also applied to two or more condensers connected to each other. A single cell is sometimes, though incorrectly, described as a battery.

Billifarad. A unit of capacity equal to one thousand millionth of a farad.

Blocking Switch. A switch, sometimes used on a wireless installation, which automatically breaks the power circuit of the transmitter, when the receiver is connected to the aerial.

Bradfield Insulator. A form of leading insulator, much used by the Marconi Company.

Brushes. The brushes on a dynamo or motor, consist of small

blocks of carbon, or strips of folded copper gauze. They are held in elastic contact, with the commutator or slip rings of the machine. Their purpose is to effect and maintain electrical connection between the fixed and moving parts of the circuit.

Brush Discharge. A *luminous* brush-like discharge which sometimes occurs when a conductor is charged to a very high voltage.

Buzzer, Sparking. A small electro-magnetic make and break, (similar to a trembler bell) used in wireless telegraphy, to produce oscillation of small amplitude for testing or measuring purposes.

Buzzer, Shunted. In construction, the same as a sparking buzzer, except that it has a non-inductive resistance connected across its coils, to eliminate the sparking at the contact breaker.

Capacity Electro-static. Ability to store energy in the form of an electro-static strain.

Change-over Switch. A switch designed to effect the speedy transference of a piece of apparatus, from one circuit to another.

Characteristic Curve. Generally, a curve showing the relation between cause and effect, when the cause is varied. The characteristic curve of a crystal shows the relation between applied volts and the current passing through the crystal.

Circuit, Electric. An electric circuit is the path followed by a current of electricity. In the case of a direct and continuous current it must of necessity consist of a completely closed path of conducting material. In the case of an alternating current it may consist in part of an insulator, as, for instance, the dielectric of a condenser.

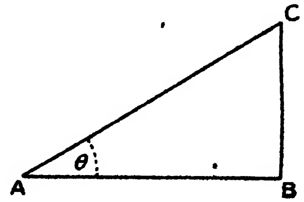
Commutator. A device for changing the direction of a current.

Condenser. An arrangement of conductors and insulators, capable of storing energy in the form of an electro-static strain.

Conductivity. The conductivity of a material is the property by virtue of which it permits a current of electricity to flow through it. The conductivity of a conductor is equal to the reciprocal of its resistance. The unit of conductivity is the Mho. Example: if the resistance of a conductor is 10 ohms, its conductivity is $\frac{1}{10}$ Mho.

Continuous Current. A direct current, which does not sensibly vary in strength.

Cosine. The cosine of an angle is the ratio between two sides of a right-angled triangle, the base AB being the numerator and the hypotenuse, AC the denominator. $\frac{AB}{AC}$ = cosine of angle.



Coulomb. The unit of electrical quantity (ampère second).

Coupling. Circuits are said to be coupled when they are so connected, or placed in respect to one another, that a transference of energy is effected.

Damping of Oscillations. Decay in amplitude, due to the using up or withdrawal of energy from the circuit. Chief sources of damping in oscillatory circuits are resistance of conductors forming circuit, spark resistance, radiation from the circuit, and dielectric hysteresis of condenser.

Detector. That part of the receiving apparatus which converts the received high-frequency currents into low-frequency currents or impulses capable of actuating a telephone receiver, or, alternatively, actuating a relay which closes a local circuit containing the indicating or recording device.

Dielectric. The insulating medium between the plates of a condenser.

Dielectric Constant. The dielectric constant of a material is a number, denoting how many times the capacity of a condenser is increased by its use, when substituted for air. The dielectic constant of air is 1.

Direct Current. A current which flows in one direction only.

Dynamo. A machine used for converting mechanical energy into electrical energy. It consists essentially of a powerful electro-magnet, termed the field-magnet, between the poles of which a system of conductors known as the armature conductors is caused to rotate. An E.M.F. is produced in the rotating conductors by electro-magnetic induction. As this E.M.F. is of an alternating nature, a commutator is provided to keep the polarity, as regards the external part of the circuit, constant.

Earth. In wireless telegraphy the earth is utilized as one plate of the condenser in the open, or radiating, circuit. On a land station the connection is made by burying in the earth a system of conductors; on a ship station, by connecting to the side of the vessel.

Earth Arrester Spark Gap. A spark gap inserted in the base of the aerial, and across which the tuner is connected. Its purpose is to automatically throw the receiver into circuit, immediately the Morse key is opened.

Eddy Current. An eddy current is an induced current in a solid mass of metal, as, for instance, the core of a transformer. They can be prevented by the lamination of the core. This breaks up the circuit in which they would flow.

Electrolyte. Any liquid which is decomposed by the passage of an electric current through it. In a cell, the exciting fluid.

Electromotive Force. The force which moves, or tends to move, electricity. Unit, the volt.

Farad. The unit of electrostatic capacity. A condenser has a capacity of one farad, when one coulomb of electricity produces a difference of potential of one volt at the terminals.

Field Regulator. A variable resistance forming part of the field circuit of a motor or a dynamo. Its purpose in the case of a motor

(D.C.) is to regulate the speed of the armature. As resistance is inserted in the field the speed of the armature is increased. The purpose in the case of a dynamo is to regulate voltage. As the resistance is inserted the voltage is reduced.

Frequency of Alternator. The frequency of an alternating current dynamo denotes the number of complete cycles of alternating current which it produces per second. Frequency = revs. per second × number of pairs of field-magnet poles.

Frequency, Natural. The natural frequency of an oscillatory circuit is the frequency determined by its own capacity and inductance. $N = \frac{5{\cdot}033 \times 10^6}{\sqrt{CL}}$; C in mfds., L in cms.

Frequency, Natural, of Aerial. The natural frequency of an aerial is the frequency determined by its own capacity with respect to earth, and by its own inductance.

Fuse. A short length of wire, the material of which and the gauge of which are so chosen that it will melt and break the circuit of which it forms part, if the normal working current is much exceeded. Its purpose is to protect the circuit from dangerously high currents.

Guard Lamps. An electric lamp having a filament of low self-inductance. The lamp is connected directly across the terminals of the alternator and shunts out any high frequency currents which may be set up in the leads, owing to the proximity of the powerful high-frequency circuits of the transmitter.

Henry. The henry is the unit of inductance.

Impedance. The sum total of all the forces opposing the flow of an alternating current. $\text{Impedance} = \sqrt{R^2 + \left(2\pi NL - \frac{1}{2\pi NK}\right)^2}$

When R = ohmic resistance, L the inductance, N the frequency, and K the capacity of the circuit.

Impedance Coil. See REACTANCE REGULATOR.

Inductance. The inertia property of a conductor, or the property which resists changes in the strength of the current flowing through it. It may also be defined as the property of a conductor by virtue of which energy, in the form of a magnetic field, can be stored or associated with it. The unit of inductance is the henry. A conductor has unit inductance if a current, varying at the rate of one ampère per second, induces at its terminals a difference of potential of one volt.

Induction Coil. An apparatus for transforming an intermittent current of low voltage into high voltage impulses.

Jigger. An oscillation transformer.

Joule. The unit of electrical energy.

Kilowatt. A unit of power equal to one thousand watts.

Logarithm. The logarithm of a number is the power to which the base of the system of logarithms must be raised to produce the given number. The base of the common logarithms is 10. The logarithm of 100 is, therefore, two, as 10, the base of the logarithms,

must be squared (10^2) to produce the number 100. The base of the Naparian system of logarithms is 2·71828.

Magnetic Detector. An instrument for converting the received high-frequency currents into currents of low frequency, capable of actuating a telephone receiver. It depends for its action on the ability of H.F. currents to annul the hysterisis of iron.

Magnetic Field. The space in and around a magnet or current-carrying conductor, permeated by lines of magnetic force.

Magnetic Key. A device which automatically maintains the continuity of an alternating current circuit, till the current is at or near zero value, and to prevent sparking at the contacts of the Morse key or switch.

Mho. The unit of conductivity. See CONDUCTIVITY.

Microfarad. A unit of capacity equal to one-millionth of a farad.

Micro-Henry. One millionth of a henry.

Micrometer Spark Gap. A finely adjustable gap connected between the Aerial and Earth terminals of a tuner. Its purpose is to protect the tuner from suddenly applied high voltages.

Milli-Microfarad. See BILLI-FARAD.

Milli-Henry. One-thousandth of a henry.

Morse Key. A form of switch designed to facilitate the closing and opening of a circuit, in accordance with the Morse code, with the maximum speed and the minimum expenditure of energy.

Motor. An electric motor is a machine for converting electrical energy into mechanical energy. In construction it is the same as the dynamo.

Motor Generator. See ROTARY TRANSFORMER. In wireless telegraphy the usual purpose of a motor generator is to convert a direct current into an alternative current.

Motor Starting Switch for D.C. Machine. A variable resistance placed in series with the armature of the machine. Its purpose is to keep the current passing through the armature at a safe value till such time as the rotation of the armature has produced a back electromotive force of sufficient magnitude for it to be dispensed with. As the back E.M.F. grows the resistance is cut out of circuit.

Multiple Tuning Switch. A number of switches mechanically coupled together, which is simultaneously varying the capacity or the inductance, of the circuits of a tuner, extend its wave-length range.

No-Volt Release. A small electro-magnet, the winding of which forms part of the field circuit of a D.C. motor, and holds the arm of the starting switch in position. Its purpose is to automatically cut the machine out of circuit, should the power supply fail, or the field circuit break.

Ohm. The unit of resistance.

Oscillatory Circuit. A circuit having capacity and inductance in series, the resistance being very small.

Oscillatory Circuit Closed. A circuit having capacity and inductance in series (the resistance being very small), the plates of the condenser being close together. An oscillatory circuit in which the

capacity and inductance are concentrated. Such a circuit is practically a non-radiator.

Oscillatory Circuit Open. An oscillatory circuit in which the capacity and inductance are distributed, as, for instance, the aerial circuit of a wireless transmitter, in which the condenser plates are the aerial wires and the earth. Such a circuit is a good radiator.

Oscillation Transformer. An apparatus by means of which energy is transferred from one oscillatory circuit to another.

Over-Load Release. An electro-magnet the coil of which forms part of the supply circuit of a D.C. motor. Its purpose is to cut the machine out of circuit should the machine be overloaded. It does this by short circuiting the coils of the No-Volt Release.

Permeability, Magnetic. The ratio between the number of lines of force per square centimeter produced by a given magnetising force in a given material, and the number of lines of force produced by the same magnetising force, per square centimeter, in air. Symbolised by the Greek letter μ. $\mu = \frac{B}{H}$. B = density of magnetic lines of force in iron or other material. H equals density of lines of force in air.

Phase. The phase of an alternating current is the stage of the cycle reached at any particular time.

Phase Difference. If the volts and ampères in an alternating circuit attain their maximum values at different times, they are said to be out of step or phase with each other.

Pilot Lamp. An electric lamp, usually mounted on the switchboard and connected directly across the main leads from the dynamo. Its purpose is to indicate whether the machine is running and generating correct voltage.

Plain Aerial Transmitter. A transmitter in which the oscillations are generated in, and radiated from, one and the same circuits.

Polarisation of Cell. A cell is said to be polarised when by reason of the deposition of gases on the elements, its action is stopped. The gases largely increase the resistance of the cell, and also produce a back E.M.F.

Poles of Cell. In a primary cell, that part of the positive plate, or element which is above the surface of the electrolyte, is termed the negative pole, that part of the negative plate which is above the surface of the electrolyte is termed the positive pole. In a secondary cell, the positive pole is the upper portion of the positive plate and the negative pole the upper portion of the negative plate.

Poles, Magnetic. The points, at or near the ends of a magnet, where the attractive force is greatest.

Potentiometer. A variable resistance, chiefly used in wireless telegraphy, to adjust the voltage applied to a detector.

Power Factor. The power factor of an A.C. circuit is equal to the cosine of the angle of lag. The cosine of the angle 90 O. Cosine of the angle O-1.

Radio Frequency. An alternating current whose frequency is above the limit of audibility (above 20,000 per second).

Reactance. That part of the total opposing force in an alternating current circuit, due to inductance, or capacity. The inductive reactance equals $2\pi NL$; the latter, which is termed the capacity reactance, equals $\frac{1}{2\pi NK}$.

Reactance Regulator. An iron-cored variable inductance forming part of an A.C. circuit. The purpose is to vary the power in the circuit. On a wireless transmitter this piece of apparatus is sometimes called the Low-Frequency Tuning Inductance.

Reciprocal. The reciprocal of a number is unity, divided by the number. As an example the reciprocal of 2 is ½, the reciprocal of 3 is ⅓.

Rectifier. An apparatus for converting alternating current into unidirectional impulses.

Resistance, High-Frequency. The resistance offered by a conductor to high-frequency currents. H.F. resistance is greater than low-frequency resistance, or the resistance to direct currents. The reason being that as the frequency is increased, the interior parts of the wire are less and less utilized for the conduction of the current. When the frequency is very high only the surface of the conductor is used.

Resonance. Identity of frequency. A number of circuits are in resonance when their frequencies are equal.

Shunt. Generally, when one conductor is connected in parallel with another, it is said to be in shunt with it. A shunt, on a galvanometer, or ampère meter, consists of a conductor of low resistance connected in parallel with the working part of the instrument. The purpose is to divert all but a small known fraction of the current. A shunt wound dynamo, or motor, is one having its field winding connected in parallel with its armature winding.

Sine. The sine of an angle is the ratio between two sides of a right-angled triangle, the side BC being the numerator, and the hypotenuse AC the denominator.

Spark Frequency. Number of sparks per second. On a transmitter using a fixed gap, the spark frequency equals twice the frequency of the alternating voltage. With a rotary gap, the spark frequency is determined by the number of studs on the rotating disc.

Spark Gap or Discharger. A gap made in the primary oscillatory circuit of a wireless transmitter to permit the condenser to charge and to automatically discharge it when maximum voltage is reached.

Tangent. The tangent of an angle is the ratio between the sides of a right-angled triangle, the side BC being the numerator and the side AB the denominator. Tangent of angle $O = \frac{BC}{AB}$.

Telephone Receiver. A polarised electro-magnet, having a soft iron diaphragm facing its pole pieces. Its purpose in wireless telegraphy is to make evident the presence of oscillatory currents in the circuits of the receiver.

Transformer, Rotary. Is a dynamo, driven by a motor, to which it is as a rule directly coupled. It may consist of a D.C. motor, driving a D.C. dynamo of lower or of higher voltage, in which case the direct voltage is stripped down or up as the case may be. It may consist of a D.C. motor driving an A.C. dynamo, in which case the direct current is transformed into an alternating current, or it may consist of an A.C. motor, driving a D.C. dynamo, in which case the A.C. is transformed into D.C.

Transformer (Static). An apparatus without moving parts, the purpose of which is to step up, or to step down, the voltage of an alternating current. It consists of two windings wound upon a laminated soft iron core which may be either of the open or the closed variety. A step-up transformer has more turns on its secondary than on its primary. A step-down transformer has more turns on its primary than on its secondary. The primary and secondary voltages are in the same ratio as the number of turns on the windings.

Tuner. An assemblage of inductances and condensers, so connected and arranged, as to enable selective reception to be carried on, usually over a large range of wave-lengths.

Tuning Lamp. A small candle-power electric lamp, connected across a suitable length of the aerial. Its purpose is to indicate by its brilliancy the attainment of resonance between the open and closed oscillatory circuits of the transmitter.

Volt. The unit of electro-motive force. The E.M.F. which produces a current of one ampère when acting through a resistance of one ohm.

Watt. The unit of electrical power equal to the product of volts and ampères.

Wave-length. The distance between two points in the medium next adjacent in the same phase. $\text{Wave-length} = \dfrac{\text{Velocity}}{\text{Frequency}}$

Wave-length, Natural. The wave-length produced by the natural frequency.

Wave-Meter. An oscillatory circuit, whose capacity or inductance is variable, and is calibrated to read wave-lengths. A detector, or indicating device of some kind, is connected to the circuit, to indicate the attainment of resonance.

Wave Motion. A motion periodic in time and space.

Wave Train Frequency. The number of trains of waves per second. One discharge of the condenser on a spark transmitter produces one train of waves; wave-train frequency and spark frequency are therefore equal.

X's. A term denoting interference due to atmospheric disturbances.

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